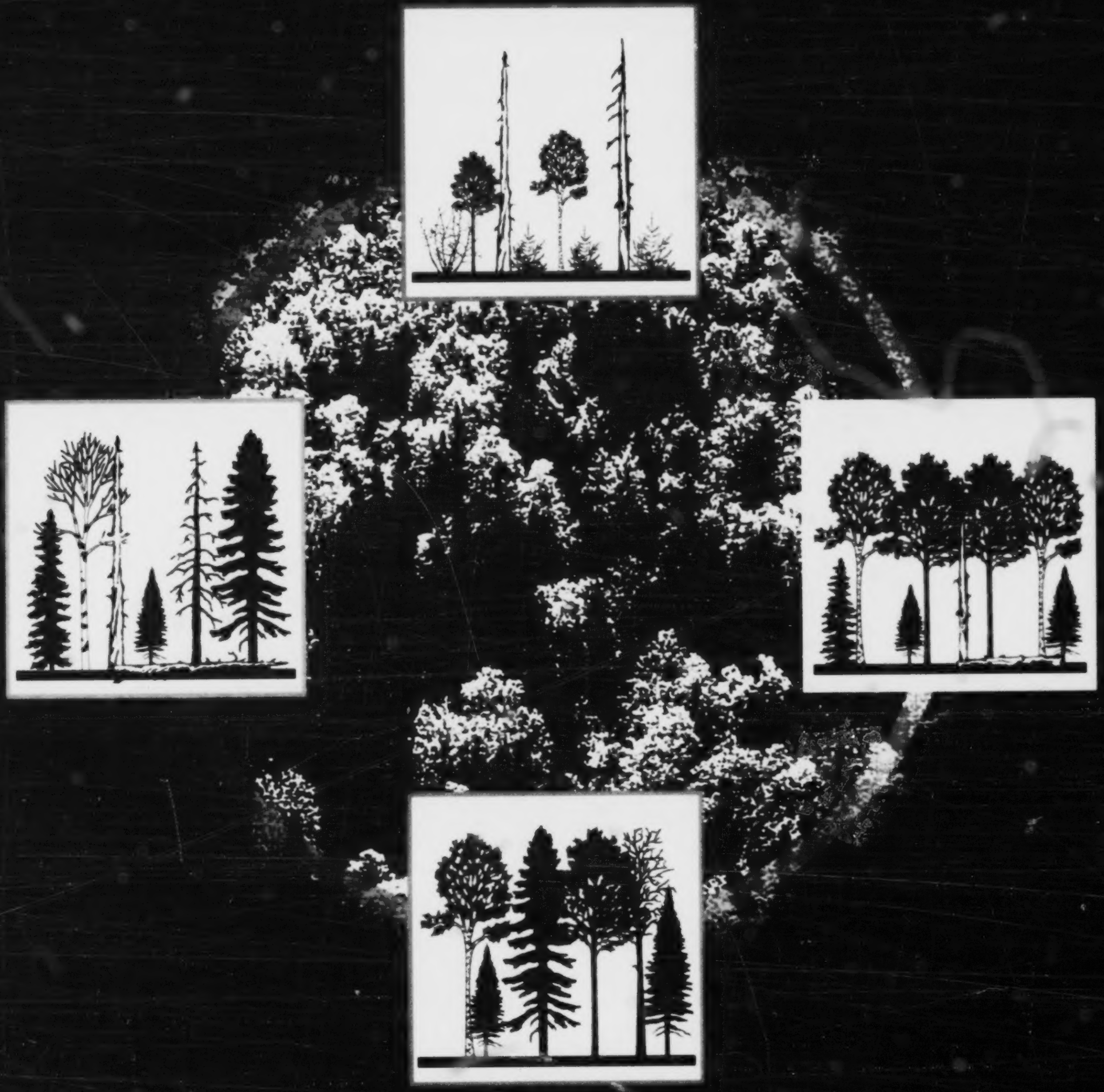
Ontario

Silviculture Guide to Managing Spruce, Fir, Birch, and Aspen Mixedwoods in Ontario's Boreal Forest



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In 1991, the Ministry of Natural Resources released a document entitled *Direction '90s* that outlines the Ministry's goals and objectives. They are based on the concept of sustainable development. This document was updated in 1994 with a new publication *Direction '90s... Moving Ahead '95*.

In 1994, OMNR finalized its Statement of Environmental Values (SEV) under Ontario's Environmental Bill of Rights (1994). The purpose of the Environmental Bill of Rights (EBR) is to ensure the integrity of the environment by protecting, conserving, and where reasonable, restoring Ontario's environment. The EBR has a public review process for new policies, acts, and regulations. In accordance with the EBR, any new policy, direction, act, instrument, or regulation must be posted on the EBR web site for public review and comment; these comments must be considered prior to final approval.

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In 2000, OMNR released a document *Beyond 2000* that reaffirms the Ministry's mission of ecological sustainability, and sets out six supporting strategies for the Ministry. Recognizing the importance of maintaining healthy and productive ecosystems across the province, *Beyond 2000* embraces the concept of sustainable development and ecological sustainability as originally expressed by the World Commission on Environment and Development. Policy and program development for Ontario's forest resources are also rooted within the long-term strategic direction provided by the Policy Framework for Sustainable Forests (OMNR 1994). These strategic directions and principles of resource management are considered in Ministry land use and resource management planning.

During the development of this silviculture guide, OMNR has considered *Direction '90s, Direction '90s...Moving Ahead '95, Beyond 2000*, and its Statement of Environmental Values. This guide is intended to reflect the directions set out in these documents and to support the objectives of managing our natural resources on a sustainable basis for future generations.

SILVICULTURE GUIDE TO MANAGING SPRUCE, FIR, BIRCH, AND ASPEN MIXEDWOODS IN ONTARIO'S BOREAL FOREST

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PREFACE

This is the *Silviculture Guide to Managing Spruce, Fir, Birch, and Aspen Mixedwoods in Ontario's Boreal Forest*. This tool recognizes the extent and importance of the boreal mixedwood forest across Ontario's forested landscapes and the significant contribution that soil and site features play in ensuring healthy and productive boreal mixedwood stands and forests. It is intended as a companion document to the *Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario* (OMNR 1997c).

Developing a silviculture guide for the boreal mixedwood forest condition in Ontario grew out of a legal requirement stated in Term and Condition 94 of the *Class Environmental Assessment for Timber Management on Crown Lands in Ontario* (OMOEE 1994). Many factors have contributed to a sense that the future health and productivity of Ontario's boreal mixedwood site and stand conditions were being compromised. These included: stand conversion from mixed hardwood-softwood stands to softwood stands, selective harvesting of higher value hardwood and softwood species in response to market conditions, poor regeneration success following harvest disturbance, and a seeming proliferation of forest health issues such as eastern spruce budworm (*Choristoneura fumiferana*).

In response, the Crown has developed two complementary publications: *Boreal Mixedwood Notes* (OMNR 2000a), and this Guide. *Boreal Mixedwood Notes* (OMNR 2000a) provide information on the ecology, silviculture, and management of boreal mixedwood sites and stands in northern Ontario. They cover a range of topics including autecology of important mixedwood species, site characteristics, silvicultural options, wildlife habitat, and disease and pest management considerations. The notes can be used as a reference for specific issues, or be read in their entirety to better understand the ecological context and philosophy of boreal mixedwood management.

The *Silviculture Guide to Managing Spruce, Fir, Birch, and Aspen Mixedwoods in Ontario's Boreal Forest* builds on the information in the *Boreal Mixedwood Notes* and provides ecological and management interpretations for boreal mixedwood site and stand conditions. Management interpretations provide specific direction to resource managers on the various silvicultural strategies and treatments to be used during the preparation and implementation of forest management plans.

Moreover, silviculture guides provide descriptions of general standard site types used to develop silvicultural ground rules in forest management plans. General standard site types provide a logical ecologically based framework for collecting, organizing, and presenting information about silvicultural strategies, tactics, and practices. Ecologically based general standard site types enable silviculturalists to identify, interpret, and address elements of species autecology, biological legacy, and forest and site productivity that may influence the achievement of a desired future stand condition. General standard site types, defined in the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996), are synonymous with ecosites, the inventory-scale classification units of Ontario's Ecological Land Classification (ELC) framework.

Guide Revision

This is one of several publications associated with the forest management planning process required by the Crown Forest Sustainability Act (CFSA) (CFSA 1994).

As a condition of Ontario Ministry of Natural Resources' (OMNR) environmental assessment approval, OMNR must undertake a review of all forest management guides on a five-year cycle to ensure that they reflect current scientific knowledge as it applies to Ontario. Revisions to this guide will be made following consultation with the Provincial Forest Technical Committee.

Note: The *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996) is currently being revised. When using this guide, please consider the applicable version.

ACKNOWLEDGEMENTS

This silviculture guide was developed by an integrated team from OMNR's Northeast Science and Information (NESI) Section, Northwest Science and Information (NWSI) Section, Forest Health and Silviculture Section (FHSS), and Ontario Forest Research Institute (OFRI).

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This Guide would not have been made possible without significant contributions of many people who provided vision and guidance during the development of this guide. In particular the development team would like to thank: Alf Aleksa, Rob Arnup, P.K. (Wally) Bidwell, Dr. Bill Crins, Alison Luke, Dr. Blake MacDonald, Dr. Brian Naylor, John Parton, Lisa Pauloff, Gerry Racey, Shannon Robertson, and Dr. Stan Vasiliauskas. We would also like to thank F. Wayne Bell, Dr. W.C. Parker, R.G. White, Julie Elliot, and D.R. Duckert for writing the original *Autecology of Selected Forest Plants* (OMNR 1997), which was modified to address mixedwood conditions and makes up Section VII of this guide.

Comments and information supplied by the following individuals and organizations are gratefully acknowledged: Dr. Art Groot, Canadian Forest Service; Richard Kabzems, British Columbia Ministry of Forests; Dr. Dan Kneeshaw, University of Quebec; and Dr. Jian Wang, Lakehead University. We thank many resource management staff from Ontario forest industry and OMNR who helped in reviewing the ecological and management interpretations in the guide.

Thanks go to Doug Skeggs for leading the design of the initial detailed document structure, and to Shelagh Duckett as project manager. Joe Churcher provided guidance for the duration of the project; his support and sense of humour were greatly appreciated.

Many thanks go to Wendy Mairs for her patience and dedication in designing and completing the desktop publishing for the Guide. All illustrations were done by Wendy Mairs with the exception of the illustration of the backpack sprayer on the cover of Section VI by Shayna LaBelle-Beadman. Cover photograph by Graeme Oxby, Timmins, Ontario. Thanks go to Annalee McColm for English editing, and Diana Callaghan who carried out the task of completing the final edit.

Finally the authors would like to thank their co-workers for their ongoing patience, support, and stress management skills which they provided to us during the development and refinement of this publication.

ABOUT THIS GUIDE

This guide contains ecological and silvicultural information for the sustainable management of certain stands of spruce-fir-birch-aspen forest mixtures in northern Ontario. For the purposes of this guide, these mixed stands growing on a selected range of soil conditions will be referred to as "boreal mixedwood stands".

This silviculture guide was developed to provide:

- definitions for boreal mixedwood sites and stands
- a synopsis of the ecology of boreal mixedwood stands
- an overview of what is currently known about boreal mixedwood silviculture in Ontario and other jurisdictions
- a repository for silvicultural experience in Ontario's boreal mixedwood forests
- a suggested approach for developing forest units and silvicultural ground rules for mixedwood objectives
- a training and educational tool

This guide is intended to provide a framework and context for generating, collecting, validating, and applying local knowledge and experience for the boreal mixedwood forests of Ontario. It is not intended to be the sole source of silvicultural information or constrain the application of sound silvicultural practices.

What's New

Because of the unique nature of boreal mixedwood sites and the methods of managing them, there are several significant differences between this document and earlier silviculture guides.

The differences include:

- experiences from other jurisdictions (especially British Columbia, Alberta, and Quebec) have been drawn upon to develop approaches to managing boreal mixedwood sites and stands in Ontario
- emphasis on management strategies that emulate natural succession
- broad soil groups and stand development stages are considered in the development of ecological and management interpretations
- emphasis on the benefits of using a pre-harvest assessment to determine the opportunities for mixedwood management options
- a "developmental" category is introduced as a treatment option

This developmental category of management treatments joins the existing categories of "recommended", "conditionally recommended", and "not recommended". Since little work has been conducted on boreal mixedwood management in Ontario, the authors have had to rely on the results of treatments in other jurisdictions. Treatments with a developmental designation are believed to be ecologically appropriate for a site, and will likely contribute to the management objectives associated with a particular stand development stage; however, these treatments have not had extensive use in boreal Ontario. Developmental treatments require a provincially-coordinated monitoring program to be described in a forest management plan. The data acquired by this monitoring program will be used to refine future versions of this guide.

How This Guide is Organized

The seven sections in this guide are described briefly below.

Section I – Introduction

Outlines the legislative and ecological context for this guide. It includes the definitions for boreal mixedwood sites and stands.

Section II – Ecological Framework

Describes the ecological factors that should be considered when managing boreal mixedwood sites. These include broad soil groups, stand composition types, and stages of stand development that apply to boreal mixedwood sites and stands discussed in this guide.

Section III – Silvicultural Practices

Defines and describes the operational practices that should be considered for boreal mixedwood site management.

Section IV – Ecological Interpretations

Describes the interactions among trees and other plants, animals, and abiotic factors associated with boreal mixedwood sites and how these factors relate to management opportunities.

Section V – Understanding the Management Interpretations

Presents the background information necessary for understanding and using the management interpretations presented in Section VI.

Section VI – Management Interpretations

Provides information about silvicultural systems, methods, and treatments that may be used on appropriate sites to achieve desired boreal mixedwood stand conditions.

Section VII – Autecology of Selected Forest Plants

Provides information relating to the growth habits, reproductive characteristics, phenology, ecophysiology, and response to disturbance for trees, shrubs, herbs, and grasses commonly found in Ontario's boreal mixedwood forests.

Relationship to Other Forest Management Guides

This document is one of a series of silviculture guides that are part of a larger group of forest management guides. Each of the silviculture guides addresses ecologically-distinct forest types in the province: jack pine, black spruce, and aspen on boreal ecosites; conifers in the Great Lakes–St. Lawrence forest region; tolerant hardwoods; and trees of the deciduous forest region. Other forest management guides cover such topics as the provision and protection of wildlife habitat, resource-based tourism and cultural heritage values, the construction of access roads and water crossings, and maintaining forest health and biodiversity.

All of these guides are used during the forest management planning process. Planning team members refer to a specific guide depending on the direction being sought. Thus, this silviculture guide provides direction only on the appropriate silvicultural practices to be followed when managing boreal mixedwood sites to reach a boreal mixedwood future stand condition consisting of spruce, fir, birch, and aspen mixtures. If a desired future stand condition as determined in the development of a forest management plan is not a boreal mixedwood, the appropriate silviculture guide should be consulted for direction.

Monitoring

Effectiveness monitoring for this guide will be conducted as described in the *Silvicultural Effectiveness Monitoring Manual for Ontario* (OMNR 2001c). The "exceptions process" (including monitoring) is required for certain categories of silvicultural practices described in this guide (OMNR 1996) (see Section VI).

Implementation

This guide will be implemented as forest management plans are renewed, commencing with the plans that come into effect April 1, 2006.

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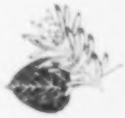

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SECTION I – INTRODUCTION

Section I introduces the reader to the *Silviculture Guide to Managing Spruce, Fir, Birch, and Aspen Mixedwoods in Ontario's Boreal Forest*. This section sets the ecological context used throughout the guide, and defines boreal mixedwood sites and stands. The opportunities for, and benefits of, practicing intentional and proactive boreal mixedwood management are also given. As well, this section provides guidance for applying the guide's site- and species-based interpretive ecological and management information during the forest management planning process. Finally, this section outlines the legislative and policy framework for sustainable forest management in Ontario.

SETTING THE ECOLOGICAL CONTEXT

Boreal mixedwoods are complex ecosystems that have developed over time in response to natural disturbances, site and soil conditions, species autecology and interactions, and cultural histories.

Traditionally the term "mixedwood" was based on the species composition of a stand at a fixed point in time (historically treated as an inventory issue) where both conifer and hardwood species were present (OMNR 1996). This inventory approach does not consider changes in species composition that may occur as a result of physical and biological factors acting on individual stems or species, or the relationship between species dominance, shade tolerance, and future stand compositions.

The boreal forest is a dynamic system where mixedwood stands are part of natural successional pathways. These pathways may be influenced by natural disturbances (e.g. fire, blowdown, insect infestations) or human intervention. In the absence of a stand-replacing disturbance (either natural or human-caused), and without subsequent human intervention, a stand generally succeeds from pioneer intolerant species in early stages, through the transition to mid-tolerant species at mid-stages, and ultimately to a complex mixture of predominantly tolerant species in later stages of succession.

What is a Boreal Mixedwood?

In Ontario, boreal mixedwood conditions have been defined by their site and stand attributes.

> A **boreal mixedwood site** *is an area with climatic, topographic and edaphic conditions that favour the production of closed canopies dominated by trembling aspen or white birch in early successional stages, black spruce or white spruce in mid-successional stages and balsam fir in late successional stages.*
>
> (MacDonald and Weingartner 1995)

Boreal mixedwood site conditions generally encompass (Pierpoint 1981, MacDonald and Weingartner 1995):

- deep, well-drained, fertile soils on mid-slope positions
- rapid incorporation of organic matter into the mineral soil
- abundant ground vegetation and species richness

Ontario's boreal mixedwood site conditions do not include wet lowlands, xeric and dry glacio-fluvial deposits, or shallow soils with strong bedrock control.

A site-based approach to define boreal mixedwood conditions was used because:

- soil conditions provide a stable framework for ecological reference
- site condition influences the biological legacy, reproductive success, and productivity of a tree species
- a relationship between site, disturbance frequency and intensity, and pre-disturbance conditions influences the development of boreal mixedwood stands
- sites that currently do not support boreal mixedwood stands may, if appropriate silviculture is applied

> A **boreal mixedwood stand** *is a tree community on a boreal mixedwood site in which no single species exceeds 80 percent of the basal area.*
>
> (MacDonald and Weingartner 1995)

When the definitions of boreal mixedwood sites and stands are compared:

- a boreal mixedwood ***stand*** must contain at least two species and be on a boreal mixedwood site; the species may differ in age or size
- a boreal mixedwood ***site*** may support one or more of the defining or associated tree species (see Table 1) at a given point in succession
- several boreal mixedwood stands may occur on a single, uniform boreal mixedwood site

Extent of This Guide

Forest conditions across northern Ontario are extremely variable, and an almost endless number of species and site combinations can be identified and managed as boreal mixedwoods. This silviculture guide provides a framework for boreal mixedwood management, and focuses on the ecological conditions that support developing and maintaining spruce-fir-birch-aspen mixtures in northern Ontario. While jack pine can be a major component of some boreal mixedwood stands in Ontario, there was insufficient documented silviculture information to provide direction on managing jack pine mixedwoods. Some information is provided in OMNR (1997c) to aid in managing jack pine and intolerant species mixtures. As our understanding of the ecology and management of all boreal mixedwood conditions (including jack pine mixedwoods) increases, a broader definition of boreal mixedwood stands will be incorporated into future versions of this guide.

For this version of the boreal mixedwood guide:

- at least one of the defining boreal mixedwood tree species (see Table 1) must be a canopy component
- there is no requirement for a hardwood/conifer mixture; for example, early successional stands can be composed of two or more intolerant pioneer hardwood species; likewise, late successional stands may be composed of shade tolerant conifer-conifer mixtures

Why Manage for Boreal Mixedwoods?

There are many reasons to manage for boreal mixedwoods, including the extent of the resource, ecological factors, achievement of multiple values, and economic considerations.

The Extent of the Resource

The range of boreal mixedwood sites and stands presently covers approximately 50 percent of the productive forests in northern Ontario (McClain 1981, Armson 1988, Towill 1996, Towill *et al.* 2003). As well, the area of Ontario's productive forest comprised of boreal mixedwood stands is increasing. A combination of past harvesting practices, increased use of natural regeneration for renewal, and greater fire suppression activities have combined to increase the total area of hardwood and mixedwood stands in second growth boreal forests (Hearnden *et al.* 1992, MacDonald 1995).

Ecological Factors

Boreal mixedwood site and stand conditions provide an ecological basis for sustainable forest management for the following reasons (MacDonald 1995):

- the resilience of ecological processes is enhanced by managing individual stands with succession and by managing for multiple species on a site
- genetic and species diversity enables an ecosystem to adapt to long-term environmental changes and recover from short-term major disturbances
- pest resistance is high because of the diversity of species on a site
- enhancement of soil nutrient status occurs; hardwoods tend to increase nutrient cycling on a site
- managing for a variety of successional stages emulates the natural successional patterns of a site

Multiple Values

The objective of maintaining mixed-species stands on the landscape is to create an environment where many values can be achieved. These include:

- high quality fibre production

Table 1. Defining and associated boreal mixedwood species.

Defining Boreal Mixedwood Species	Associated Boreal Mixedwood Species	
Trembling aspen (*Populus tremuloides)*	Jack pine (*Pinus banksiana)*	Large tooth aspen (*Populus grandidentata)*
White birch (*Betula papyrifera)*	White pine (*Pinus strobus)*	Balsam poplar (*Populus balsamifera* ssp. *balsamifera)*
Black spruce (*Picea mariana)*	Red pine (*Pinus resinosa)*	White elm (*Ulmus americana)*
White spruce (*Picea glauca)*	White cedar (*Thuja occidentalis)*	Black ash (*Fraxinus nigra)*
Balsam fir (*Abies balsamea)*	Tamarack (*Larix laricina)*	

(adapted from MacDonald and Weingartner 1995)

- improved aesthetics due to the variability of the landscapes
- more recreational opportunities
- diverse wildlife habitat

Economic Considerations

Boreal mixedwood site and stand conditions may provide (MacDonald 1995):

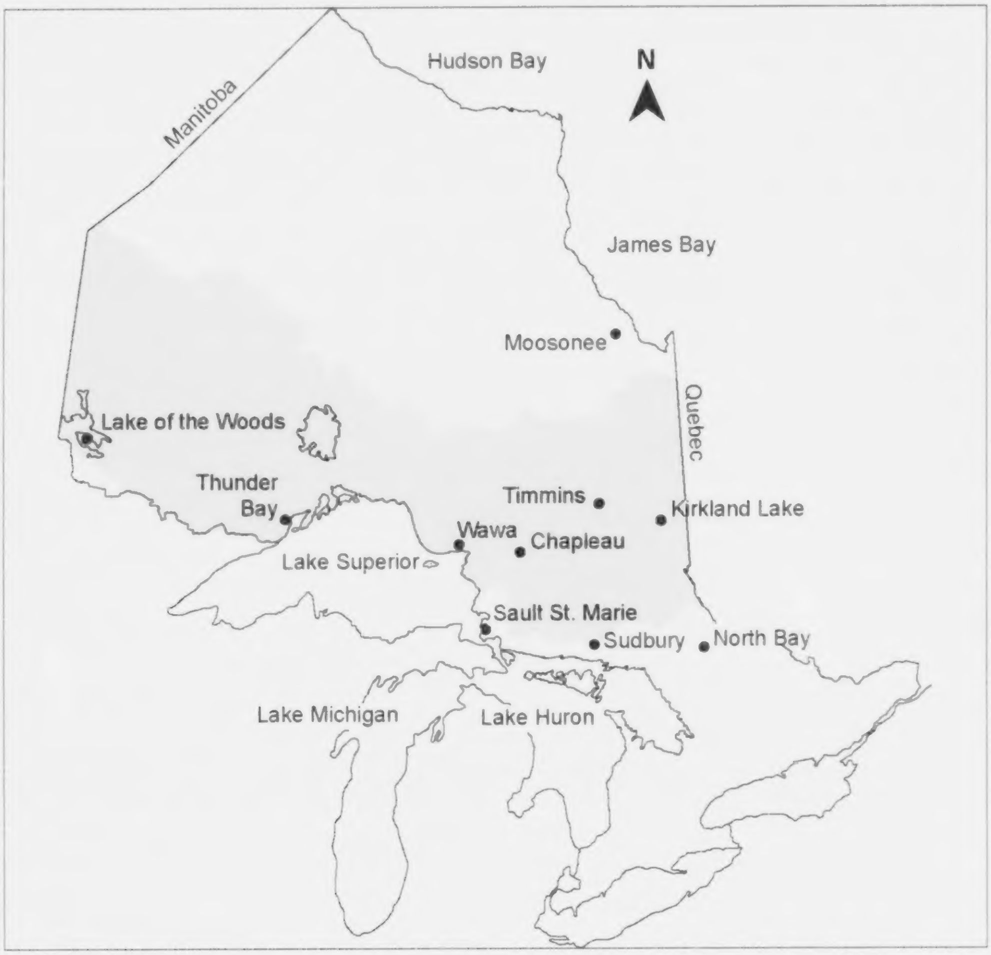
- sources of high-quality wood
- product diversity – a broad range of species is available
- year-round harvesting opportunities
- inexpensive regeneration by managing with succession
- high total yields per hectare

Geographic Distribution of Boreal Mixedwoods in Ontario

In Ontario, boreal mixedwood sites and stands occur throughout the boreal forest and the Boreal–Great Lakes–St. Lawrence transitional forest (Figure 1). They extend between the 48° N and 53° N latitudes, and from Manitoba in the west to Quebec in the east. The northern boundary coincides with climatic indicators of potential evapo-transpiration and the 13° C mean July temperature isotherm (Royal Commission of the Northern Environment 1985). The southern boundary is more difficult to discern because of the mixture of species and the lack of distinct, persistent species associations in the Boreal–Great Lakes–St. Lawrence transitional forest (Hare 1950, Maycock and Curtis 1960, Sims and Uhlig 1996). However, it corresponds roughly to the 5° C mean annual isotherm east of Lake Superior and the 4° C annual isotherm to the west (Thompson 2000). Mean annual temperatures are 0° to 3° C and the mean annual precipitation is 700 to 950 millimetres (Rowe 1972, Sims and Uhlig 1996, Chen and Popadiouk 2002). There may be isolated stands located beyond the southern boundary where conditions meet the definition of a boreal mixedwood. Forest managers encountering these locations may choose to refer to this guide for management direction.

The Ontario Shield Ecozone contains nine ecoregions, six of which are included in the geographic area covered by this guide (3S, 3W, 3E, 4S, 4W, and 4E). These ecoregions are differentiated based on broad regional climatic regimes that influence vegetation distribution and productivity (Crins and Gray, in prep.). Moving from north to south across the province and between ecoregions, there is an increase in temperature. Moving from west to east, there is a general increase in humidity. Major continental air masses and the relative positions of the major water bodies within the province contribute to these trends. Differences in temperature, precipitation, and associated disturbance patterns (type, frequency, and intensity) between the six ecoregions are outlined in Appendix 1. Because of these differences, silvicultural practices may in some cases, vary among ecoregions.

Figure 1. Ontario's boreal forest and the Boreal–Great Lakes–St. Lawrence transitional forest.


Hudson Bay
N
Manitoba
James Bay
Moosonee
Quebec
Lake of the Woods
Thunder Bay
Timmins
Kirkland Lake
Wawa
Chapleau
Lake Superior
Sault St. Marie
Sudbury
North Bay
Lake Michigan
Lake Huron

AN ECOLOGICAL APPROACH TO FOREST MANAGEMENT

Managing for Biodiversity

In the strategic direction statements *Direction '90s* (OMNR 1991b), *Direction '90s…Moving Ahead 1995* (OMNR 1995a), and *Beyond 2000* (OMNR 2000b), the OMNR embraced sustainable development as a business principle. This direction calls for an ecosystem-based (ecological) approach to the management of Ontario's natural resources. Adopting an ecological approach to management involved a change in emphasis, from resource extraction to one that maintains healthy ecosystems for future use.

This relatively new focus of maintaining sustainable healthy ecosystems over time requires an understanding of the variability amongst living organisms and the ecological complexes in which they can occur (biodiversity). One way of viewing biodiversity is by looking at ecosystem composition, structure, and function over different spatial scales (Noss 1990). This framework can be used to identify the components of biodiversity in forest management (Table 2).

Forest management planning influences stand composition and structure largely through the silvicultural treatments prescribed in silvicultural

Table 2. A framework for identifying the critical components of biological diversity in forest management (adapted from Noss 1990).

	Composition	Structure	Function
Landscape (forest)	Area Selected for Harvest		
	area of each forest type	size, shape and spacing of patches	fire and insect spread
	age class distribution	corridors	habitat and wood supply
Site (stand)	Silvicultural Ground Rules		
	species composition – all layers	snags, coarse woody debris, super-canopy trees, multi-storied canopies	habitat suitability, nutrient cycling
Population	relative abundance/biomass of species	age/sex ratios	fertility, recruitment, mortality rates
Gene	number of different alleles, presence of rare alleles	effective population size, heritability, overlap	inbreeding depression, genetic drift, mutation rates

ground rules and forest operations prescriptions. Silvicultural ground rules and treatment packages (see page 8) are developed to meet management objectives and are based on a knowledge and understanding of stand and site attributes (OMNR 1996).

Silvicultural ground rules seek to achieve specific types of desired future stand conditions, while sustaining ecosystem health. The most effective silvicultural treatments are often innovative applications of intervention that come from an intimate understanding of the prevailing natural processes on a site.

Forest ecosystems, or ecosites, are the basis for both ground rules and prescriptions.

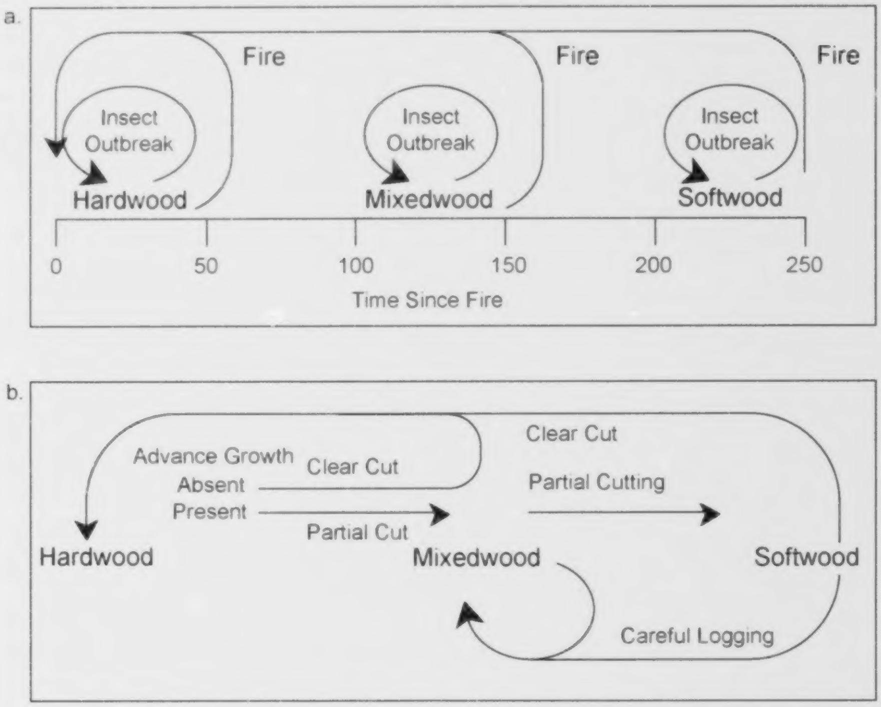
Managing with Succession

The primary principle underlying Ontario's approach to mixedwood management is to design and implement silvicultural treatment packages that direct future stand development according to natural successional patterns (MacDonald 1995) to meet strategic objectives established in a forest management plan. By "managing with succession", opportunities exist to use regeneration strategies that capitalize on the biological legacy of a boreal mixedwood site or stand, influencing the development of a desired future stand condition while maintaining the ecological processes of a site.

Bergeron and Harvey (1997) have proposed a similar approach for mixedwood conditions in Quebec's southern boreal forests (Figure 2). Following a stand-replacing disturbance like fire, a stand goes through an early stage dominated by intolerant hardwoods that colonize the site. If left undisturbed, the stand will naturally develop over time into a mixed stand of intolerant hardwood and tolerant softwood (conifer) species. If the stand continues to remain undisturbed it will then develop into a future softwood dominated mixedwood (see Section II).

At each successional stage the stand may experience disturbances (insects, disease, wind, fire, etc.). Depending on the severity of the disturbance, the stand's successional pathway may be altered. For example, the stand may remain in its current stage or return to a previous successional stage. Bergeron and Harvey (1997) suggest that natural successional patterns can be emulated through silvicultural practices. This approach to management forms the basis of this guide.

Figure 2. Successional patterns in Quebec's boreal forest (a) and silvicultural emulation of these patterns (b) (Bergeron and Harvey 1998).


a.
Fire
Fire
Fire
Insect Outbreak
Insect Outbreak
Insect Outbreak
Hardwood
Mixedwood
Softwood
0
50
100
150
200
250
Time Since Fire
b.
Advance Growth
Absent
Present
Clear Cut
Partial Cut
Clear Cut
Partial Cutting
Hardwood
Mixedwood
Softwood
Careful Logging

Achieving a future softwood dominated stand condition as a result of directing a stand through the various successional stages by means of successive silvicultural interventions requires detailed planning and long-term documentation. The *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996) requires that silvicultural strategies for each of the forest units being described are recorded in the forest management plan.

It is important to understand that the silvicultural ground rules and treatment packages described in a forest management plan (OMNR 1996) detail only those prescribed silvicultural activities that move a stand or group of stands with similar attributes from a current stand condition to a desired future stand condition in one sequenced intervention. Thus, it is necessary to ensure that silvicultural ground rules are available for all combinations of current stand composition types/successional stages where canopy manipulation may be undertaken. The silvicultural strategy for emulating natural successional patterns in boreal mixedwoods, therefore, consists of one or more sequenced interventions. These "related" silvicultural ground rules are linked by virtue of sharing a common broad soil group (see Section II). They also share a common end (future stand condition) and beginning (current stand condition) point such that they can be "linked together" along a temporal scale.

Organizing our Silvicultural Knowledge: Use of General Standard Site Types

Forests are complex systems with many interactions among species and environmental conditions. A forest ecosystem classification simplifies this complexity, so that patterns and common features can be recognized and applied at a practical management level. Information from a forest ecosystem classification, such as a description of ecological units like ecosites, is one tool that can help resource managers to develop silvicultural prescriptions. However, no classification system can encompass all of the complexity and diversity in a landscape.

The *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996) requires that ecosites be used as building blocks to describe forest units when modelling forest sustainability, developing silvicultural ground rules, and reporting forest operations prescriptions within annual work schedules. Ecosites are an appropriate tool for describing a productive forest landbase and for use in other forest management planning applications at this scale.

Ecosites are defined in terms of abiotic (soil depth, texture, moisture regime, hydrology, and nutrient regime) and biotic (plant community structure and composition) factors. In fact, ecosites may represent different stages of stand development. Some silvicultural considerations may be broadly interpreted from a description of an ecosite, including: tree growth and yield; vigour of competing species; potential advance growth and ingress of naturals; and site hazard potential, such as rutting and compaction.

Some of these factors, such as forest productivity and vigour of competing species, will vary for a given soil condition when there are variations in climate. Therefore, interpretations for an ecosite must be considered in a broader ecological context (e.g. ecoregions and ecodistricts).

An ecosite-based forest inventory can help resource managers model forest development, assess sustainability, and identify candidate boreal mixedwood sites. However, given the complex nature of boreal mixedwood sites, more stand level information on stand composition and structure will be needed to fully implement boreal mixedwood prescriptions. This information is best obtained from a field-based inspection of the candidate site (referred to here as a pre-harvest assessment) to assess the variability of individual stand components and to verify soil and site conditions.

Confirmation of this additional information, as part of the forest operation prescription verification process, should be completed before a boreal mixedwood silvicultural prescription is implemented. Some of the key factors to be noted in such a pre-harvest field assessment include:

- soil conditions (confirming a boreal mixedwood site)
- tree species and vigour of all vegetative strata (including advance growth)
- stand structure and development stage
- seedbed conditions

Identifying these features and their distribution within a stand, is the key to successfully implementing boreal mixedwood prescriptions. More details on this topic are provided in Section V, and an example of a form that may be helpful in gathering this additional information is in Appendix 5.

SETTING THE MANAGEMENT CONTEXT

Sections IV, V, and VI provide guidance for the application of site- and species-based interpretative ecological and management information during the forest management planning process. However, this boreal mixedwood guide is only one of many sources of information to be consulted when preparing silvicultural ground rules. Silvicultural knowledge and experience gained by members of a local forest management planning team is also a critical component.

Building Forest Units

For management purposes, a forest unit is an aggregation of forest stands that have similar species composition, develop in a similar manner (both naturally and in response to silvicultural treatments), and are managed under the same silvicultural system (OMNR 1996). While ecological factors provide the basis for defining forest units, other considerations such as economics and product requirements may also be addressed. Typically, forest units are specific to the needs of each forest management unit.

From an ecological perspective, derivation of forest units is generally best achieved using ecosites as building blocks; forest units will eventually be linked with specific ecosites to describe current stand conditions. In the absence of mapped forest ecosites, forest resource inventory information (species composition, age, site class, and stocking) can be integrated with local knowledge and existing sources of ecological information to build forest units.

The descriptions of forest units may be somewhat broad when they are based on ecosites. However, by definition, the description of a forest unit must be specific enough to imply a predictable pattern of development. For boreal mixedwood management, forest units can be refined using species composition and stand development stages. Section II establishes boreal mixedwood stand composition types and stand development stages and identifies four broad soil-based ecosite groupings that should be considered when deriving boreal mixedwood forest units.

Forest units developed for boreal mixedwood conditions should consider previously established "Regional Standard Forest Units" in order to facilitate modelling and comparison of modelling results between adjacent forests, ecodistricts, and ecoregions.

Developing Silvicultural Ground Rules

Silvicultural ground rules are specifications, standards, and other instructions that direct forest management practices on a forest management unit during the period of a forest management plan (OMNR 1996). Each ground rule is a unique combination of three components: current stand condition, future stand condition, and a silvicultural treatment package. Silvicultural ground rules must be developed based on the requirements of the current forest management planning manual.

Silvicultural ground rules are developed within the context of forest level management objectives, while providing stand level direction. These ground rules serve as inputs to the analysis tools used to project forest development; care must be taken to select appropriate silvicultural activities to achieve the desired future stand condition. One of the most important aspects in creating silvicultural ground rules is the construction of ecologically-based forest units.

Preparing Silvicultural Treatment Packages

Silvicultural treatment packages refer to a range of acceptable treatments (harvest, renewal, and tending) on the appropriate forest unit that can be undertaken at various intervals throughout the life of a stand to achieve a desired future stand condition (OMNR 1996). For each current forest unit/site type combination, one or more harvest-to-harvest strings of activities may be described to achieve the predicted future stand condition. Each silvicultural treatment package includes: a silvicultural system, harvest method, logging method, renewal treatments (site preparation and regeneration), tending treatments, and regeneration standards.

DEVELOPING SILVICULTURAL GROUND RULES WITH THIS GUIDE

Silvicultural ground rules are included in every forest management plan. A number of components must be specified to complete the description of a silvicultural ground rule. The categories below refer to portions of a silvicultural ground rules table and explain where information in this guide may be applicable.

Current Forest Stand Conditions

Forest Unit

Forest resource inventory parameters and other criteria may be used to assign a stand to a forest unit (for developing forest units, see Building Forest Units, described previously and Appendix 2). Sections II and IV of this guide provide the ecological framework for understanding ecosite groupings useful in defining boreal mixedwood forest units.

Site Type

The ecosites, or portions of ecosites, that are used to define a forest unit will be identified in the ground rule. The identification of ecosites will provide information about abiotic (e.g. soil depth, texture, and moisture regime), and biotic (overstorey and understorey condition) factors that will determine the silvicultural treatment package selected.

For boreal mixedwood management, specific stand characteristics may be identified as additional prerequisites for implementing a particular silvicultural treatment package. This information can include: species composition and distribution, stand structure, stage of development, understorey condition, and status of advance growth.

Sections IV and VI should be consulted to identify the critical stand characteristics necessary for developing management strategies for boreal mixedwoods. These key features must be identified in the "site type" description of the silvicultural ground rule. They must also be confirmed during the verification of the forest operation prescription before the silvicultural ground rule may be implemented.

Future Forest Stand Conditions

Silviculture is used to direct a stand from its current condition to a desired future stand condition. To ensure a stand develops as desired, action may need to be taken before, during, and after harvest. Boreal mixedwood management often involves repeated silvicultural interventions, the results of which must be carefully monitored.

The ability to predict future stand conditions begins with an understanding of species autecology and their associations on a site and how various silvicultural treatments affect future stand development. Section II summarizes the ecological framework upon which the management of boreal mixedwoods in this guide is based. Section VII provides specific autecological information for boreal mixedwood plant and tree species.

Forest Unit

Depending on the management objectives and silvicultural treatment packages, a current forest unit may be directed to a variety of future forest units. Individual silvicultural ground rules must describe only one future forest unit. Sections II and IV of this guide provide the ecological framework for understanding ecosite groupings useful in defining potential future forest units.

Development Information

Development information reflects predicted future stand development from the application of each silvicultural ground rule. Typically, these are yield curves for selected tree species but, depending on the management objectives, could be yield curves for other stand attributes like snag density or browse production.

The yield curves assigned to each future forest unit are used to assess forest sustainability. For boreal mixedwood management, development information should be identified by broad soil group (see Section II), species composition types (see Section II), and silviculture intensity class (e.g. present, extensive, basic, and intensive).

Stand Characteristics

Future species composition and stand structure following application of a silvicultural ground rule must also be described. Stand structure may describe a stand as a mixedwood mosaic (species in discrete patches or intermixed) or as a stratified mixedwood (species separated in understorey and overstorey). These stand characteristics must be described for a specific future stand development stage (e.g. canopy transition). Species composition at other stand development stages or ages, and additional information such as stand density or product, may also be included.

Silvicultural Treatment Package Components

Section III outlines silvicultural practices appropriate for boreal mixedwood management in Ontario. The tables and fact sheets in Section VI provide information for understanding and applying management interpretations in specific boreal mixedwood conditions.

Silvicultural System

Boreal mixedwood management may involve one of three silvicultural systems: clearcut, shelterwood, or selection. The choice of silvicultural system is related to the management objectives, the current forest composition and stage of stand development, and the capacity of the tree species to regenerate and grow under certain ecological conditions.

The management interpretations outlined in Section VI identify those silvicultural systems specific to current stand conditions and targeted future stand conditions.

Harvest Method

Harvest method is a term used to further define or modify one of the three basic silvicultural systems, specifically the harvesting component or technique (e.g. strip clearcut). It defines the timing and pattern of removal and distribution of residual stems.

Sections III, IV, and VI provide information on harvest methods.

Logging Method

There are three logging methods to choose from: full-tree, tree-length, and cut-to-length (shortwood). The choice of logging method will have an impact on the selection of renewal treatments.

Ecosite descriptions offer information on stand composition, depth of organic matter, soil moisture, and soil texture that, when combined with logging method, will affect associated renewal treatments such as site preparation, regeneration, and tending.

Site characteristics, limitations, and hazard potential are considerations that may direct the selection of an alternate logging method (e.g. sites associated with steep slopes or rutting potential). When there are logging method options, the circumstances under which the different methods will be used should be indicated (e.g. special conditions determining the type of logging equipment or season of harvest).

Sections III and VI provide guidance on recommended logging methods for mixedwood conditions.

Regeneration

Ecosite information will include information on soil and vegetation characteristics that could affect the selection of a regeneration method. A pre-harvest assessment should be conducted to confirm the pre-harvest stand structure and composition that will be considered in the selection of a regeneration strategy. Species, quantity and quality of advance growth, and the probability of natural ingress will also be assessed, resulting in a decision about whether these components form part of a regeneration strategy. Site productivity information can be used to help select target species for renewal.

Information in Sections III, IV, and VI can be used to develop options for regeneration.

Site Preparation

Site preparation treatments may be prescribed for a portion of a stand (directed) or throughout the stand (broadcast). The choice of a site preparation technique may vary if advance growth is to be relied on to form part of the new stand. The probability and density of natural ingress are related to seedbed condition and may also affect the choice of site preparation technique.

The interaction between site preparation and reproductive strategies for potential competing species should also be assessed. The potential for site damage under certain ecological conditions must also be considered.

Sections III, IV, VI, and VII include information regarding the selection of site preparation treatments.

Tending Treatments

Tending treatments include cleaning and intermediate stand treatments. Cleaning treatments may be applied throughout the stand (broadcast) or only on certain species or portions of the stand (directed). The method of tending (e.g. manual, chemical, chemi-mechanical, etc.) may also be indicated.

Other tending and intermediate stand treatments include juvenile spacing, pre-commercial thinning, compositional treatment, liberation treatment, and commercial thinning.

Information regarding tending treatments and methods is found in Sections III, IV, VI, and VII.

Regeneration Standards

Regeneration standards are the benchmarks for determining if a silvicultural treatment package is moving a stand from the current stand condition to the desired future stand condition. These standards must relate to the future stand characteristics and associated yield curves. The requirements for regeneration standards are specified in the *Silviculture Effectiveness Monitoring Manual for Ontario* (2001c).

Sections V and VI provide further guidance and discussion concerning the establishment of regeneration standards for boreal mixedwood stand conditions.

Preferred and Exception Activities

Refer to the *Forest Management Planning Manual for Ontario's Crown Forest* (OMNR 1996) for direction about "preferred silvicultural treatment packages".

Silvicultural treatment packages that contain activities that are not in accord with the provincial silviculture guides (i.e. are not included in this or other silviculture guides or are "not recommended" or "developmental" activities), may still be permissible but must be noted as an "exception." Further direction on exceptions is found in the *Forest Management Planning Manual for Ontario's Crown Forest* (OMNR 1996).

LEGISLATIVE AND POLICY FRAMEWORK FOR SUSTAINABLE FORESTS

The context for forest management in Ontario is the *Policy Framework for Sustainable Forests* (OMNR 1995c). The policy framework states that the goal for management of Ontario's forests is:

> *"...to ensure the long-term health of our forest ecosystems for the benefit of the local and global environments while enabling present and future generations to meet their material and social needs."*

This framework sets the broad direction for forest policy and establishes forest sustainability as the primary objective for long-term forest health and the sustainable development of forest resources.

The legislative authority for OMNR to establish forest sustainability as the primary objective of forest management is found in the CFSA (CFSA 1994). The CFSA is enabling legislation that provides for the regulation of: forest planning, information, licensing, trust funds, processing facilities, remedies, enforcement, and transitional provisions. The Act allows for the management of all forest-based values.

The CFSA requires the creation of four regulated manuals that provide details of forest planning, forest information, the scaling of timber, and the standards to be followed when conducting forest operations (CFSA 1994). Ontario provides the standards and guidelines for forest operations conducted on Crown land in a series of guides, such as this silviculture guide. Each of these guides is listed in the *Forest Operations and Silviculture Manual* (OMNR 1995b). It is through this regulated document that forest managers are required to follow the direction included in this silviculture guide.

The CFSA defines sustainability as long-term Crown forest health. It defines forest health as the condition of a forest ecosystem that sustains an ecosystem's complexity while providing for the needs of the people of Ontario.

One of the guiding principles of the Act states:

> *"The long term health and vigour of the Crown forest should be provided for by using forest practices that, within the limits of silvicultural requirements, emulate natural disturbances and landscape patterns while minimizing adverse effects on plant life, animal life, water, soil, air and social and economic values, including recreational values and heritage values."* (CFSA, Section 1(3):2)

Applying silvicultural systems, harvesting methods, and regeneration treatments that emulate natural disturbances at the landscape, stand, and individual tree level is an important part of Ontario's approach to forest management. The *Forest Management Guide for Natural Disturbance Pattern Emulation* (NDPE) (OMNR 2001b) provides direction for resource managers about creating landscape patterns, structural legacy, and residual stand structures that resemble post wildfire conditions. Boreal mixedwood stands have a high retention of structural attributes following wildfire (insular and peninsular residual patches; individual residual trees; large, dead, and downed woody debris) and offer significant opportunities for retaining or creating these structural attributes in conjunction with harvesting.

The NDPE guide (OMNR 2001b) also considers the importance of forest conditions with an uneven-aged stand structure. Silvicultural systems, harvest methods, and renewal treatments can be employed to create future stand conditions with compositional and structural elements associated with late successional conditions or those derived from non-stand-replacing disturbances (i.e. low intensity surface fires, insect- and disease-related mortality). The NDPE guide (OMNR 2001b) also identifies the importance of employing natural and/or assisted natural regeneration where it is appropriate to sites and species, and where it has proven reliable as a means to produce the desired future stand condition.

The development of objectives and measurable targets associated with a planned future stand condition is an important aspect of evaluating forest sustainability. Strategies can then be developed and implemented that will assist in achieving desirable future stand conditions and related objectives. This guide provides information on various silvicultural systems, harvesting methods, and renewal treatments that can be used to manipulate stand structure, composition, and site utilization to favour a desired future boreal mixedwood stand condition identified during the planning process.

Monitoring and evaluating future stand conditions compared to planned outcomes provides a means for continual refinement, redevelopment, and improvement of OMNR's silvicultural strategies and practices. The achievement of desired future stand conditions is based on our understanding of forest ecosystems and the application of management practices consistent with our understanding. This mixedwood guide provides some of the silvicultural concepts and tools to make this possible. For related information and operational direction see the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996), *Forest Operations and Silviculture Manual* (OMNR 1995b), and the *Silvicultural Effectiveness Monitoring Manual for Ontario* (OMNR 2001c).

SECTION II – ECOLOGICAL FRAMEWORK

Section II provides the ecological framework for the management of boreal mixedwood sites presented in this guide. Site-specific and species-specific silvicultural treatments, which emulate natural disturbances and processes, are the basis for boreal mixedwood management. This section describes the following:

- broad soil groups that constitute boreal mixedwood sites
- stand composition types (tree species mixtures) that represent current and desired future stand conditions
- relationships among broad soil groups, stand composition types, and ecosites
- stages of stand development on boreal mixedwood sites
- an overview of important factors influencing stand development

More detailed information on individual factors that influence stand development on boreal mixedwood sites can be found in Section IV, Ecological Interpretations.

BROAD SOIL GROUPS

Boreal mixedwood sites have been classified into four broad soil groups: coarse, medium, fine, and moist mineral. In the order listed, these soil groups roughly represent a moisture gradient from dry/fresh to moist, while the nutrient gradient is somewhat more complex. These four soil groups are described below.

Coarse

The "coarse" broad soil group is characterized by sandy to coarse loamy soils. Coarse soils have a low water-holding capacity and are usually well aerated. These soils tend to be both drier and more nutrient poor than soils in the medium or fine broad soil groups. For the purpose of this guide, coarse soils are limited to fresh (2) to very fresh (3) moisture regimes (OCSRE 1993).

Medium

The "medium" broad soil group is characterized by medium loamy to silty soils. Soils in this group are generally intermediate in moisture and nutrient ranges compared to coarse- and fine-textured soils. Within the medium soil category, boreal mixedwood sites are limited to those with a fresh (2) to very fresh (3) moisture regime (OCSRE 1993).

Fine

The "fine" broad soil group is characterized by fine loamy to clayey soils. Fine-textured soils tend to be rich in nutrients but poorly aerated. This broad soil group is limited to sites with a fresh (2) to very fresh (3) moisture regime (OCSRE 1993).

Moist Mineral

In contrast to the coarse, medium, and fine soil groups, the "moist mineral" broad soil group is defined by moisture regime instead of texture. Specifically, the moist mineral broad soil group is defined by soils with a moderately moist (4) to moist (5) moisture regime (OCSRE 1993). Sites in this group can vary greatly in nutrient richness.

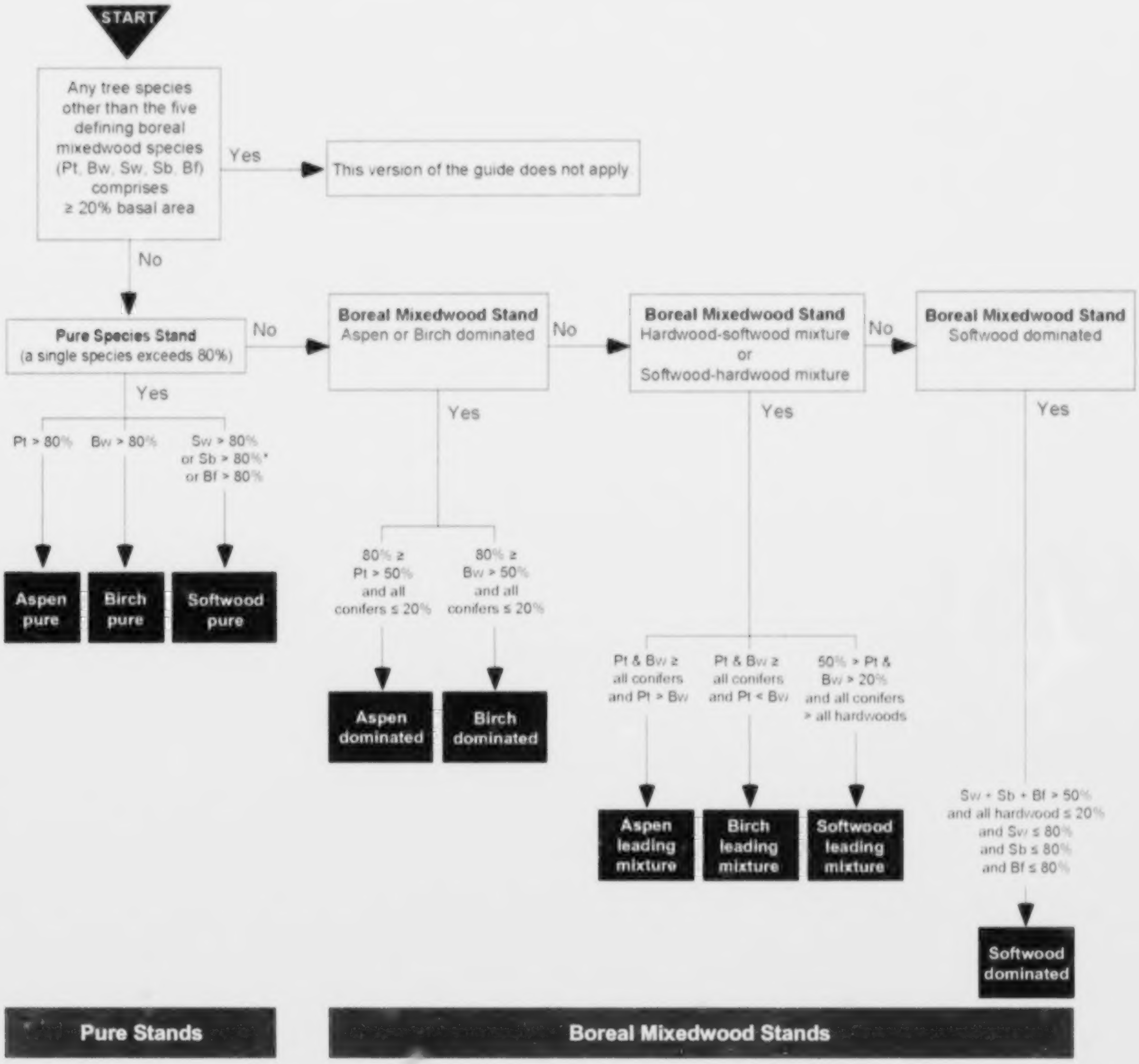
STAND COMPOSITION TYPES

Fifteen generalized stand composition types are described as stand conditions for boreal mixedwood management in this guide:

- there are nine composition types (including pure stand types) that may be used to describe **current** stand conditions (Figure 1)
- there are six composition types that may be used to describe **future** stand conditions (Table 1)

Stands must be classified into these composition types to use the information in Section VI (Management Interpretations). Stand composition types may be related in a general fashion to forest units used for strategic level modelling (OMNR 1996).

Figure 1. Nine generalized stand composition types used to describe **current** stand conditions on boreal mixedwood sites.


START
Any tree species other than the five defining boreal mixedwood species (Pt, Bw, Sw, Sb, Bf) comprises ≥ 20% basal area
Yes
This version of the guide does not apply
No
Pure Species Stand
(a single species exceeds 80%)
No
Boreal Mixedwood Stand
Aspen or Birch dominated
No
Boreal Mixedwood Stand
Hardwood-softwood mixture
or
Softwood-hardwood mixture
No
Boreal Mixedwood Stand
Softwood dominated
Yes
Pt > 80%
Bw > 80%
Sw > 80%
or Sb > 80%*
or Bf > 80%
Aspen pure
Birch pure
Softwood pure
Yes
80% ≥ Pt > 50% and all conifers ≤ 20%
80% ≥ Bw > 50% and all conifers ≤ 20%
Aspen dominated
Birch dominated
Yes
Pt & Bw ≥ all conifers and Pt > Bw
Pt & Bw ≥ all conifers and Pt < Bw
50% > Pt & Bw > 20% and all conifers > all hardwoods
Aspen leading mixture
Birch leading mixture
Softwood leading mixture
Yes
Sw + Sb + Bf > 50% and all hardwood ≤ 20% and Sw ≤ 80% and Sb ≤ 80% and Bf ≤ 80%
Softwood dominated
Pure Stands
Boreal Mixedwood Stands

* Cannot be a Black Spruce – Feathermoss community (Northwest ES14 and ES20)

Species codes: Pt, Trembling aspen; Bw, White birch; Sw, White spruce; Sb, Black spruce; and Bf, Balsam fir.

Table 1. Six generalized stand composition types used to describe eligible **future** stand conditions on boreal mixedwood sites

Boreal Mixedwood Stands (no single species exceeds 80%)			
	Hardwood dominated		Hardwood-softwood mixtures
Stand Type	Aspen dominated	Birch dominated	Aspen leading mixtures
Icon	🌳🌳	🌳🌳	🌳🌲
Composition (% basal area)	Pt + Bw ≥ 80% & Pt ≤ 80% & Pt > Bw	Bw + Pt ≥ 80% & Bw ≤ 80% & Bw > Pt	80% > (Pt + Bw) ≥ 50% & 50% ≥ (Sw + Sb + Bf) > 20% & Pt ≥ Bw
	Hardwood-softwood mixtures		Softwood dominated
Stand Type	Birch leading mixtures	Softwood leading mixtures	Softwood dominated
Icon	🌳🌲	🌲🌳	🌲🌲
Composition (% basal area)	80% > (Bw + Pt) ≥ 50% & 50% ≥ (Sw + Sb + Bf) > 20% & Bw > Pt	80% > (Sw + Sb + Bf) > 50% & 50% > (Pt + Bw) > 20%	Sw + Sb + Bf ≥ 80% & Sw ≤ 80% & Sb ≤ 80% & Bf ≤ 80%

Species codes: Pt, Trembling aspen; Bw, White birch; Sw, White spruce; Sb, Black spruce; and Bf, Balsam fir.

GENERAL STANDARD SITE TYPES

Table 2 lists the ecosites in the Northwest Region (Racey *et al.* 1996) and Northeast Region (Taylor *et al.* 2000) associated with each of the broad soil groups. An ecosite is a mapping unit that integrates a consistent set of environmental factors and vegetation conditions. Ecosites are generally comprised of a number of vegetation and soil types (ecoelements) (Sims *et al.* 1997). Vegetation types are mature forest plant communities based on species composition and abundance, while soil types are classified on the basis of soil texture, depth, moisture regime, calcareousness, and forest humus form. Within each of the broad soil groups, some of the ecosites may be related at different stages of stand development. When developing management strategies, therefore, the possible seral relationships between ecosites within a broad soil group should be considered.

Tables 3 and 4 show the relationship between ecosites, soil types, vegetation types, broad soil groups, and stand composition types. When preparing silvicultural ground rules, soil and vegetation types may be used to modify ecosite descriptions to provide a more thorough description of site and stand conditions and refine the prediction of silvicultural treatment impacts.

Table 2. Ecosites (ES) associated with each of the four broad soil groups on boreal mixedwood sites in the Northwest and Northeast regions (after Racey *et al.* 1996, Taylor *et al.* 2000).

Northwest Region Ecosites		Northeast Region Ecosites	
Coarse Soil		**Coarse Soil**	
ES16	Hardwood – Fir – Spruce Mixedwood: Sandy Soil	ES3	White Birch – Trembling Aspen – Black Spruce: Coarse Soil
ES19	Hardwood – Fir – Spruce Mixedwood: Fresh, Sandy – Coarse Loamy Soil	ES6c	Trembling Aspen – Black Spruce – Jack Pine: Coarse Soil
ES21	Fir – Spruce Mixedwood: Fresh, Coarse Loamy Soil	ES7c	Trembling Aspen – White Birch: Coarse Soil
Medium Soil		**Medium Soil**	
ES27	Fir – Spruce Mixedwood: Fresh, Silty – Fine Loamy Soil	ES5m	Black Spruce: Medium Soil
ES28	Hardwood – Fir – Spruce Mixedwood: Fresh, Silty Soil	ES6m	Trembling Aspen – Black Spruce – Balsam Fir: Medium Soil
		ES7m	Trembling Aspen – White Birch: Medium Soil
Fine Soil		**Fine Soil**	
ES26	Spruce – Pine / Feathermoss: Fresh, Fine Loamy – Clayey Soil	ES5f	Black Spruce: Fine Soil
ES27	Fir – Spruce Mixedwood: Fresh, Silty – Fine Loamy Soil	ES6f	Black Spruce – Trembling Aspen: Fine Soil
ES29	Hardwood – Fir – Spruce Mixedwood: Fresh, Fine Loamy – Clayey Soil	ES7f	Trembling Aspen – White Spruce – White Birch: Fine Soil
ES30	Black Ash Hardwood: Fresh, Silty – Clayey Soil		
Moist Mineral Soil		**Moist Mineral Soil**	
ES23	Hardwood – Fir – Spruce Mixedwood: Moist, Sandy – Coarse Loamy Soil	ES9r	White Spruce – Balsam Fir – White Cedar: Moist Soil – Species Rich
ES31	Spruce – Pine / Feathermoss: Moist, Silty – Clayey Soil	ES10	Trembling Aspen – Black Spruce – Balsam Poplar: Moist Soil
ES32	Fir – Spruce Mixedwood: Moist, Silty – Clayey Soil		
ES33	Hardwood – Fir – Spruce Mixedwood: Moist, Silty – Clayey Soil		

Table 3. Relationships among broad soil groups, stand composition types, ecosites (ES), soil types (S), and vegetation types (V) on Northwest Region boreal mixedwood sites (after Racey *et al.* 1996, Sims *et al.* 1997).

Stand Composition Type (Current or Future)	Coarse Soil	Medium Soil	Fine Soil	Moist Mineral Soil
Aspen pure and/or dominated	**ES19** S2, S3 V5, V8	**ES28** S4, SS7 V5, V8	**ES29** S6, SS7 V5, V8	**ES23** S7, S8, SS8 V5, V8 **ES33** S9, S10, S11, SS8 V5, V8
Birch pure and/or dominated	**ES19** S2, S3 V4			
Aspen leading mixture	**ES16** S2, SS5 V6, V8, V9, V10 **ES19** S2, S3 V6, V8, V9, V10	**ES28** S4, SS7 V6, V8, V9, V10	**ES29** S6, SS7 V6, V7, V8, V9 **ES 30** S6 V1, V2	**ES23** S7, S8, SS8 V6, V7, V8, V9 **ES33** S9, S10, S11, SS8 V5, V6, V7, V8
Birch leading mixture	**ES19** S2, S3, SS6 V4			
Softwood leading mixture	**ES21** S3, SS6 V14, V15, V16, V19	**ES27** S4, S5, SS7 V14, V15, V16, V19	**ES26** S6, SS7 V20, V31, V19 **ES27** S6, SS7 V14, V15, V16	**ES32** S9, S10, SS8 V14, V15, V16, V19
Softwood pure and/or dominated	**ES21** S3, SS6 V24, V25	**ES27** S4, S5, SS7 V24, V25	**ES27** S6, SS7 V24, V25	**ES32** S9, S10, SS8 V24 **ES31** S9, S10, SS7, SS8 V31

Table 4. Relationships among broad soil groups, generalized stand composition types, ecosites (ES), soil types (S), and vegetation types (V) on Northeast Region boreal mixedwood sites (after Taylor *et al.* 2000).

Stand Composition Type (Current or Future)	Coarse Soil	Medium Soil	Fine Soil	Moist Mineral Soil
Aspen pure and/or dominated	**ES6c** S1, S2, S3, S5, S8 V4, V8 **ES7c** S1, S2, S5, S7 V4, V5	**ES6m** S10, S11, S12 V8, V10 **ES7m** S9, S10, S11 V5, V8, V12, V13	**ES7f** S13, S14 V4, V5, V10, V12, V13	**ES9r** S15, S16 V8, V13 **ES10** S15, S16 V8, V10, V13
Birch pure and/or dominated	**ES3** S1, S3, S5, S7 V6, V7	**ES7m** S9, S10, S11 V1, V4, V13		**ES10** S15, S16 V13
Aspen leading mixture	**ES3** S1, S3, S5, S7 V6, V8 **ES6c** S1, S2, S3, S5, S6, S8 V4, V8	**ES6m** S10, S11, S12 V8, V10 **ES7m** S9, S10, S11 V4, V5, V8, V12, V13	**ES6f** S13, S14 V8, V10, V11, V12, V15 **ES7f** S13, S14 V4, V5, V10, V12, V13	**ES9r** S15, S16 V8, V13, V15 **ES10** S15, S16 V8, V10, V13
Birch leading mixture	**ES3** S1, S3, S5, S7 V6, V7	**ES7m** S9, S10, S11 V1, V4		**ES9r** S15, S16 V1, V13 **ES10** S15, S16 V16
Softwood leading mixture	**ES6c** S1, S2, S3, S5, S6, S8 V8, V15	**ES5m** S9, S12 V8, V19, V20	**ES5f** S13, S14 V15, V23 **ES6f** S13, S14 V8, V10, V11, V12, V15	**ES9r** S15, S16 V8, V15, V16 **ES10** S15, S16 V8, V15
Softwood pure and/or dominated		**ES5m** S9, S12 V17, V19, V20, V27	**ES5f** S13, S14 V20, V23, V24	**ES9r** S15, S16 V14, V15, V16

Fact sheets for each of the ecosites described in this guide are provided in Appendix 3 for northwestern Ontario ecosites and Appendix 4 for northeastern Ontario ecosites.

STAND CONDITION

For the purpose of the management interpretations (Section VI) stand condition specifically refers to a combination of stand composition type and stand development stage. It may be used to describe current or future composition types and stand development stages, as in "current stand condition" or "desired future stand condition". The stages of stand development are discussed below.

STAND DEVELOPMENT ON BOREAL MIXEDWOOD SITES

The concept of emulating natural changes in tree species composition and stand structure through silviculture is addressed partly through reference to the stand development stage. The material presented below describes the four stages of stand development used in this guide and the factors influencing stand development. These stand development stages may differ from those used in some other planning tools.

Stand Development Stages

Following a stand-replacing disturbance, such as a large intense fire, natural stand development on boreal mixedwood sites may pass through four sequential stages of stand development (Figure 2). Partly as a result of changes in canopy cover, the relative dominance of shade intolerant versus shade-tolerant tree species can undergo distinct changes during stand development. Boreal mixedwood sites favour: the dominance of shade-intolerant trembling aspen and white birch in early successional stages; shade-tolerant black spruce or white spruce in mid-successional stages; and very shade-tolerant balsam fir in later successional stages (MacDonald and Weingartner 1995). Associated boreal mixedwood tree species may also be present.

A general description of the characteristics of each stand development stage follows (based on Chen and Popadiouk 2002).

Stand Initiation Stage

The stand initiation stage (Figure 2a) begins following a major disturbance that destroys most or all of the mature trees on a site. Structurally, this stage is characterized by openness and the availability of growing space for newly establishing trees (i.e. the canopy is not closed), and a legacy of standing and downed coarse woody debris (remnants). After trees are established, inherently fast-growing shade-intolerant pioneer tree species (typically trembling aspen and white birch) begin to dominate in height over inherently slower growing, more shade-tolerant conifers where present (typically spruce and fir).

Stem Exclusion Stage

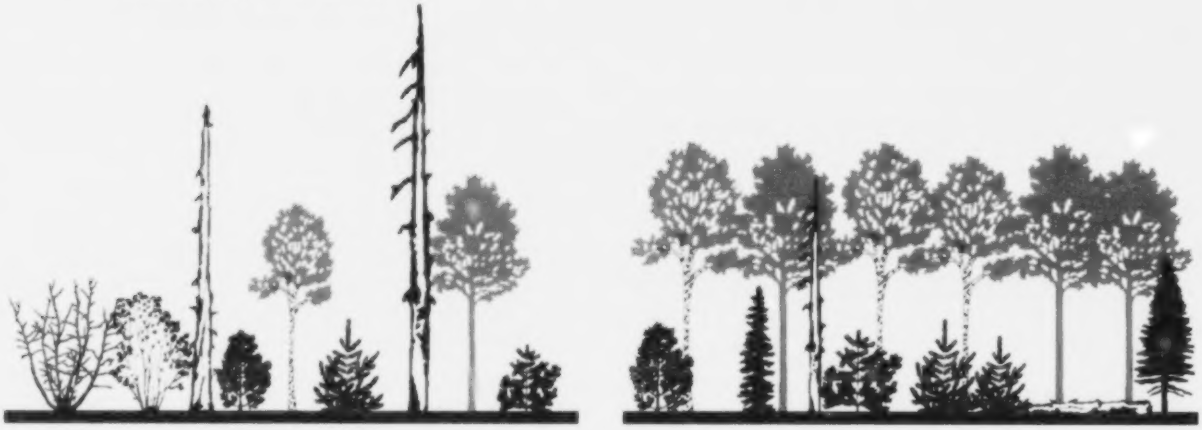
The stem exclusion stage begins with a fully closed tree canopy that does not allow crown space for any new trees (Figure 2b). Where multiple species have been established, shade-intolerant species tend to dominate. Shade from these intolerant species may suppress any slower growing, shade-tolerant species. Intense competition may occur within and between species and self-thinning of the overstorey eventually takes place.

Depending on site conditions, shade-tolerant conifers may or may not begin, or continue, to become established under the closed canopy of shade-intolerant species. Where slower growing, shade-tolerant species persist (either from the initial or subsequent cohorts), vertical stratification of the canopy may occur (i.e. the canopy may develop into two or more vertically distinct layers). If the stand remains even-aged and is made up of a single species or multiple species with similar height growth rates, the canopy tends to form a single layer.

Canopy Transition Stage

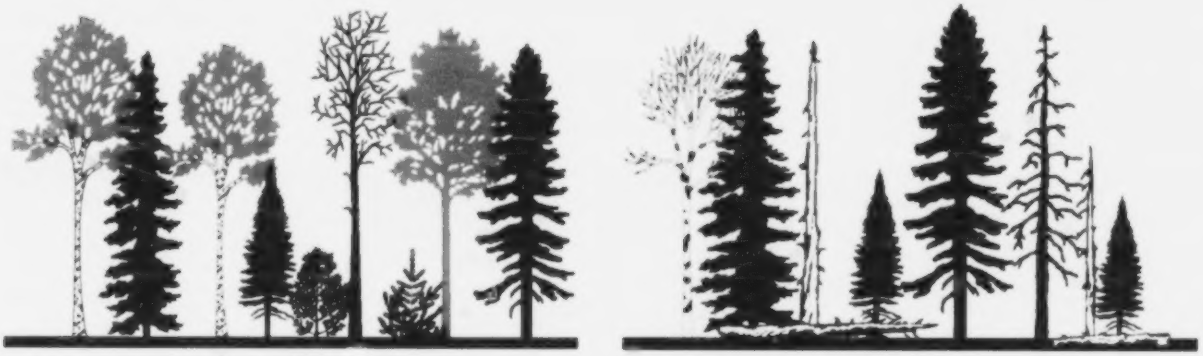
The canopy transition stage (Figure 2c) starts when gaps form between canopy trees from the initial cohort as they begin to decline and die from age-related mortality and/or non-stand-replacing disturbances such as insects, disease, or small-scale windthrow. When these canopy trees die, understorey

Figure 2. A representation of the four sequential stages of stand development on boreal mixedwood sites (adapted from Chen and Popadiouk 2002).



a. Stand Initiation

b. Stem Exclusion



c. Canopy Transition

d. Gap Dynamics

light levels increase and subordinate shade-tolerant conifers, where present, may accelerate growth towards the main canopy. Gradually over a period of many years, the initial cohort of canopy trees will be replaced by shade-tolerant species. Stands without an understorey of conifers do not show a transition of understorey conifers to the overstorey when canopy gaps form.

Structurally, the canopy transition stage is characterized by the presence of canopy gaps that effectively limit crown competition between canopy trees. Initially, the stand may be vertically stratified, but stratification may be lost as understorey conifers grow into the main canopy. New trees may also become established in recently formed canopy gaps and these new recruits may renew the stratified structure. This stand development stage ends when all of the individuals that dominated the stand at the stem exclusion stage have died.

Gap Dynamics Stage

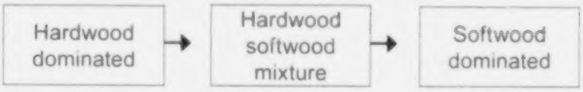
The gap dynamics stage is the final stage of stand development (Figure 2d). Stands progress to this stage if no stand-replacing disturbances occur within the life span of the original cohort of dominant trees. This stage is characterized by an uneven-aged, multi-layered, multi-species canopy (vertical diversification), with scattered openings (gaps) of various sizes and origins (horizontal diversification). Gaps form when individual trees or groups of trees die, either through age-related mortality or non-stand-replacing disturbances. Such gaps may or may not contain standing dead trees. Coarse woody debris is often abundant on the forest floor.

Compared to the canopy transition stage, the individuals remaining at this stage are not the trees that dominated the canopy at the stem exclusion stage. Rather, individuals have arisen from saplings suppressed at earlier stages or through self-perpetuation. Accordingly, species composition shifts towards dominance by shade-tolerant species capable of surviving and regenerating beneath the overstorey. Shade-intolerant tree species such as aspen and birch may also continue to become established, but generally only within the confines of larger gaps that occur less frequently. Thus, the gap dynamics stage can be maintained as a shifting mosaic of patch disturbances resulting in a variety of young, mature, and dying trees of varied species throughout the stand. This condition has been variously termed "steady-state", "true old growth", and "shifting-gap phase".

If, through natural succession, conditions become inadequate for tree regeneration, a shrubland may result. This condition is often characterized by extensive cover of woody shrub species (e.g. beaked hazel [*Corylus cornuta* ssp. *cornuta*], mountain maple [*Acer spicatum*], and green alder [*Alnus viridis* ssp. *crispa*]) interspersed with occasional tree stems. Fine soils and moist mineral soils often support broad coverage of woody species such as wild red raspberry [*Rubus idaeus* ssp. *melanolasius*] or graminoids (Canada blue-joint [*Calamagrostis canadensis*]) and sedges (*Carex* spp.).

Changes in Tree Species Composition During Stand Development

The preceding stand development description represents a simplified view of boreal mixedwood stand dynamics. An important source of variation is tree species composition and its associated effects on vertical stand structure. The classic natural successional pathway on boreal mixedwood sites after a stand-replacing disturbance shows a change in the proportion of shade-intolerant hardwood species to more shade-tolerant conifer species as follows:



However, succession on a boreal mixedwood site does not necessarily begin with a hardwood dominated stand. Succession could initiate with any one of a variety of stand composition types that could be supported on these sites (Figure 3). Note that although the relative representation of hardwood species to softwood (conifer) species can vary considerably among initial stand types, subsequent succession tends to lead directionally to the same end point wherever conditions are suitable for regeneration (Figure 3). Where conditions are inadequate for regeneration, a shrubland may result through natural succession.

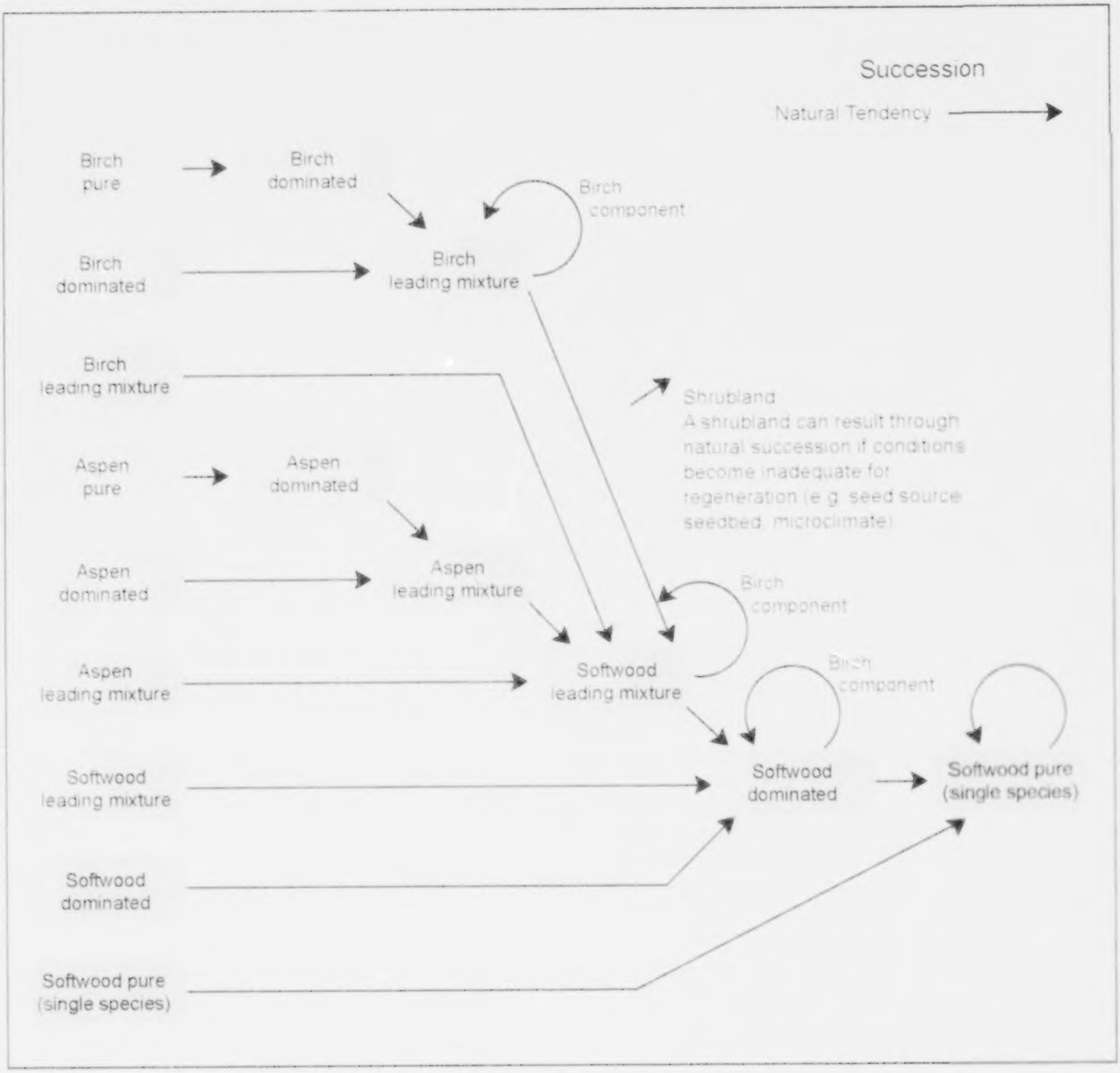
Factors Influencing Stand Development

At any given stand development stage, tree species life history traits can interact with several factors to influence tree species composition (i.e. the abundance and diversity of species). These traits include: dispersal characteristics for seeds and asexual propagules (timing of production, dispersal distance as a function of seed characteristics); shade and exposure tolerance; moisture and nutrient requirements; height growth potential (competitive ability); natural longevity; and susceptibility to damaging agents. On boreal mixedwood sites, tree species traits can interact with:

- availability of seeds and asexual propagules from pre-disturbance and neighbouring stands
- availability of seedbeds and surface conditions for establishment
- environmental conditions (climate, microclimate, and site quality)
- vegetative competition
- non-stand-replacing disturbances in which only individual trees or groups of trees are affected (e.g. insect and disease damage; herbivory; wind, snow, and ice damage; and non-catastrophic fires)

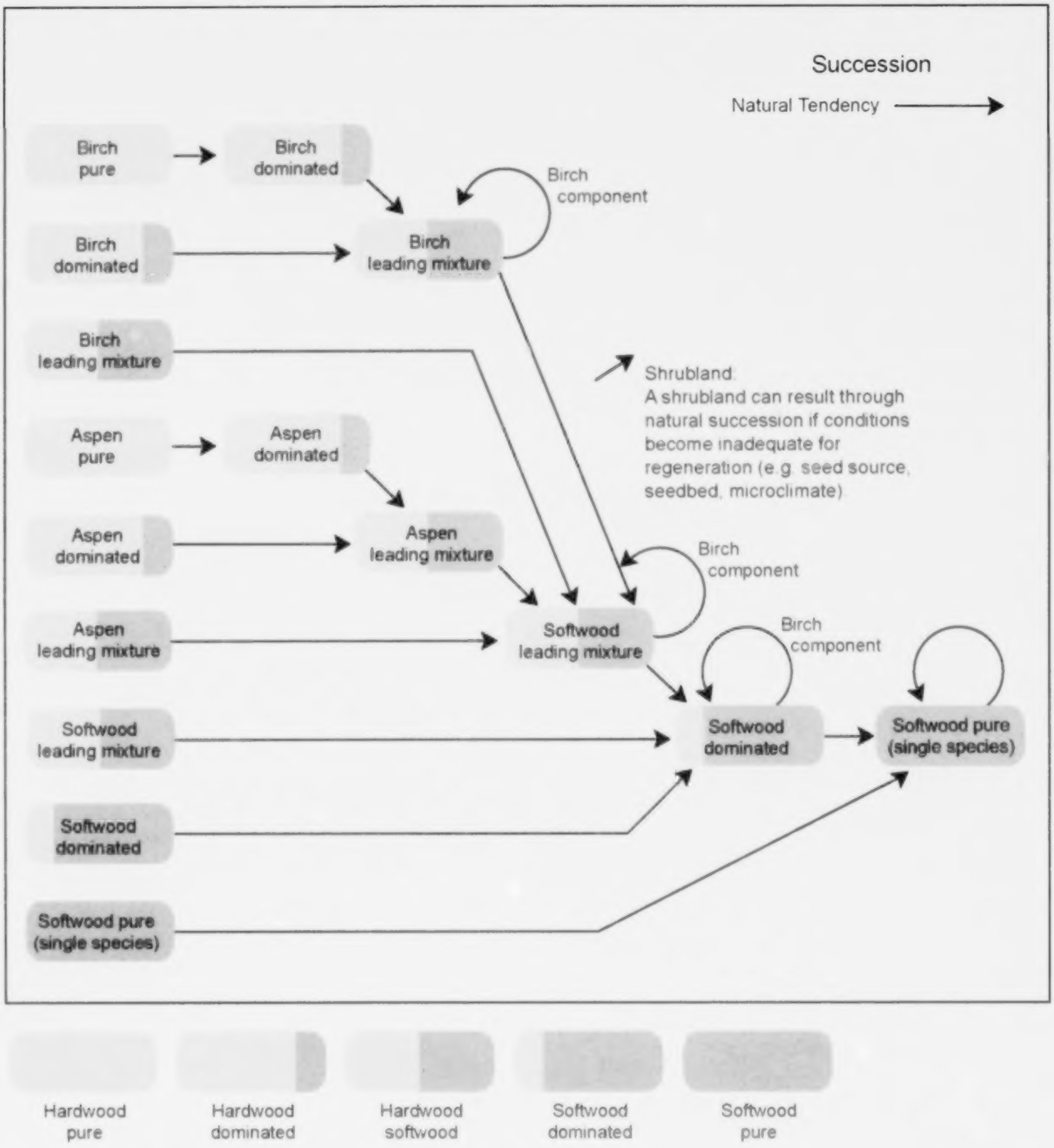
Understanding the factors that drive stand development is essential to managing boreal mixedwoods and designing silvicultural strategies to emulate natural developmental processes. How these factors influence stand development on boreal

Figure 3. Conceptual successional sequences for nine current stand composition types on boreal mixedwood sites.


Succession
Natural Tendency
Birch pure
Birch dominated
Birch component
Birch dominated
Birch leading mixture
Birch leading mixture
Shrubland
A shrubland can result through natural succession if conditions become inadequate for regeneration (e.g. seed source seedbed, microclimate)
Aspen pure
Aspen dominated
Aspen dominated
Aspen leading mixture
Birch component
Aspen leading mixture
Softwood leading mixture
Birch component
Softwood leading mixture
Softwood dominated
Softwood pure (single species)
Softwood dominated
Softwood pure (single species)

Hardwood pure
Hardwood dominated
Hardwood softwood
Softwood dominated
Softwood pure

Figure 3. Conceptual successional sequences for nine current stand composition types on boreal mixedwood sites.


Succession
Natural Tendency
Birch pure
Birch dominated
Birch dominated
Birch leading mixture
Birch component
Birch leading mixture
Aspen pure
Aspen dominated
Aspen dominated
Aspen leading mixture
Aspen leading mixture
Softwood leading mixture
Birch component
Birch component
Softwood leading mixture
Softwood dominated
Softwood pure (single species)
Softwood dominated
Softwood pure (single species)
Shrubland.
A shrubland can result through natural succession if conditions become inadequate for regeneration (e.g. seed source, seedbed, microclimate).
Hardwood pure
Hardwood dominated
Hardwood softwood
Softwood dominated
Softwood pure

mixedwood sites is described below (based on Chen and Popadiouk 2002).

The discussion that follows assumes an initial stand-replacing disturbance, such as severe fire, that destroys most trees and vegetation. Initially, the result of such a disturbance is high light levels, warm soil temperatures, the release or flush of nutrients locked up in organic material, and the creation of ample suitable seedbeds for most boreal tree species. Succession will proceed but, at any point along subsequent successional pathways, a stand-replacing disturbance can set stand development back to the stand initiation stage and to many different stand composition types (Figure 4).

Availability of Seeds and Asexual Propagules

An important factor determining the composition of tree species in an initiating stand is the distribution and abundance of tree species in pre-disturbance and/or neighbouring stands. Pre-disturbance stand composition influences post-disturbance stand composition by leaving asexual buds and/or seeds that can survive a stand-replacing fire (i.e. through self-replacement). Neighbouring stands may influence post-disturbance stand composition by contributing seed (i.e. through new inputs). The availability of asexual buds and viable seeds is a critical factor driving stand development on boreal mixedwood sites.

Trembling aspen, white birch, and black spruce are defining boreal mixedwood tree species capable of regenerating large burns through asexual buds and/or seeds that often (but not always) survive a stand-replacing fire. Shade-intolerant aspen and birch can recolonize vegetatively from surviving root suckers and stump sprouts, respectively. Shade-tolerant black spruce can recolonize from seeds contained within semi-serotinous cones.

Other boreal tree species are generally established through seed from neighbouring stands. The representation of these species in the new stand will, at least initially, be dependent on the availability of these seed sources, and on the distance from these sources. Because seed production varies with tree age (reproductive maturity) and through time, the timing of the disturbance is important. Establishment potential is lower for all species in years with low seed production than in years with high seed production.

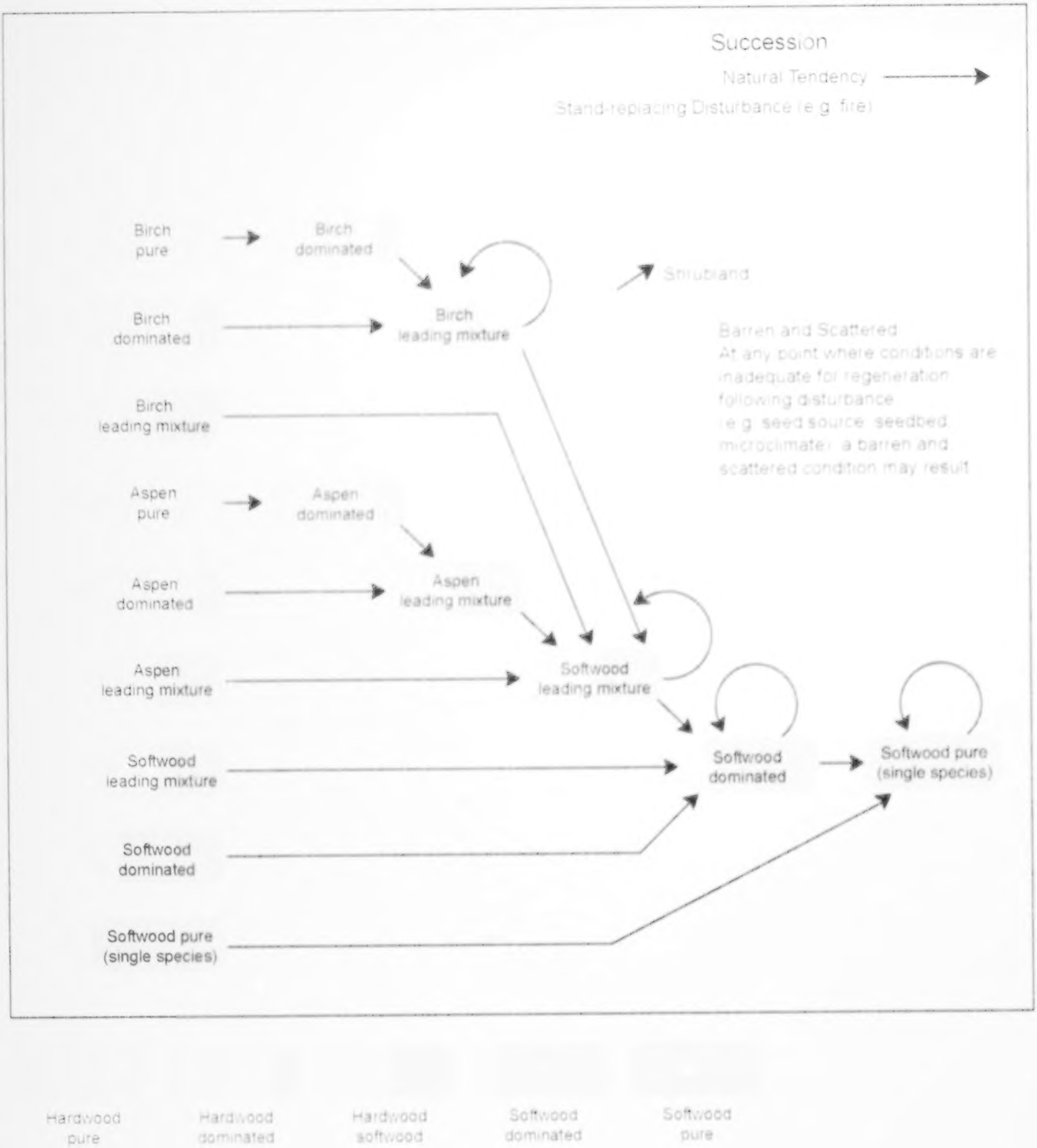
Although the species composition of a stand can be largely determined during the stand initiation stage, recruitment of new individuals may also occur during later stand development stages. As in the initiation stage, successful establishment of a species at later stages of stand development depends on the availability of seeds and/or asexual propagules and the availability of seedbeds and surface conditions suitable for successful establishment.

Availability of Seedbeds and Surface Conditions Suitable for Establishment

Suitable seedbed and surface conditions are required for successful establishment of boreal tree species. For example, aspen suckering is promoted by warm root zone temperatures and exposed mineral soil is suitable as a seedbed for most boreal tree species. Because of these preferences, a stand-replacing fire is likely to provide, at least initially, ideal substrate conditions for the establishment of most boreal tree species by exposing mineral soil and allowing unimpeded soil warming. However, these conditions are quickly lost as vegetation is established and litter accumulates. In fact, optimal seedbeds for boreal tree species generally become uncommon within five to seven years after a stand-replacing disturbance. After that, establishment by seed rarely occurs for any of the defining boreal mixedwood species except balsam fir. Unlike most other boreal tree species, balsam fir can be established relatively well on undisturbed organic seedbeds. This tendency, and a high tolerance to shade, contributes to the dominance of balsam fir in late successional stages.

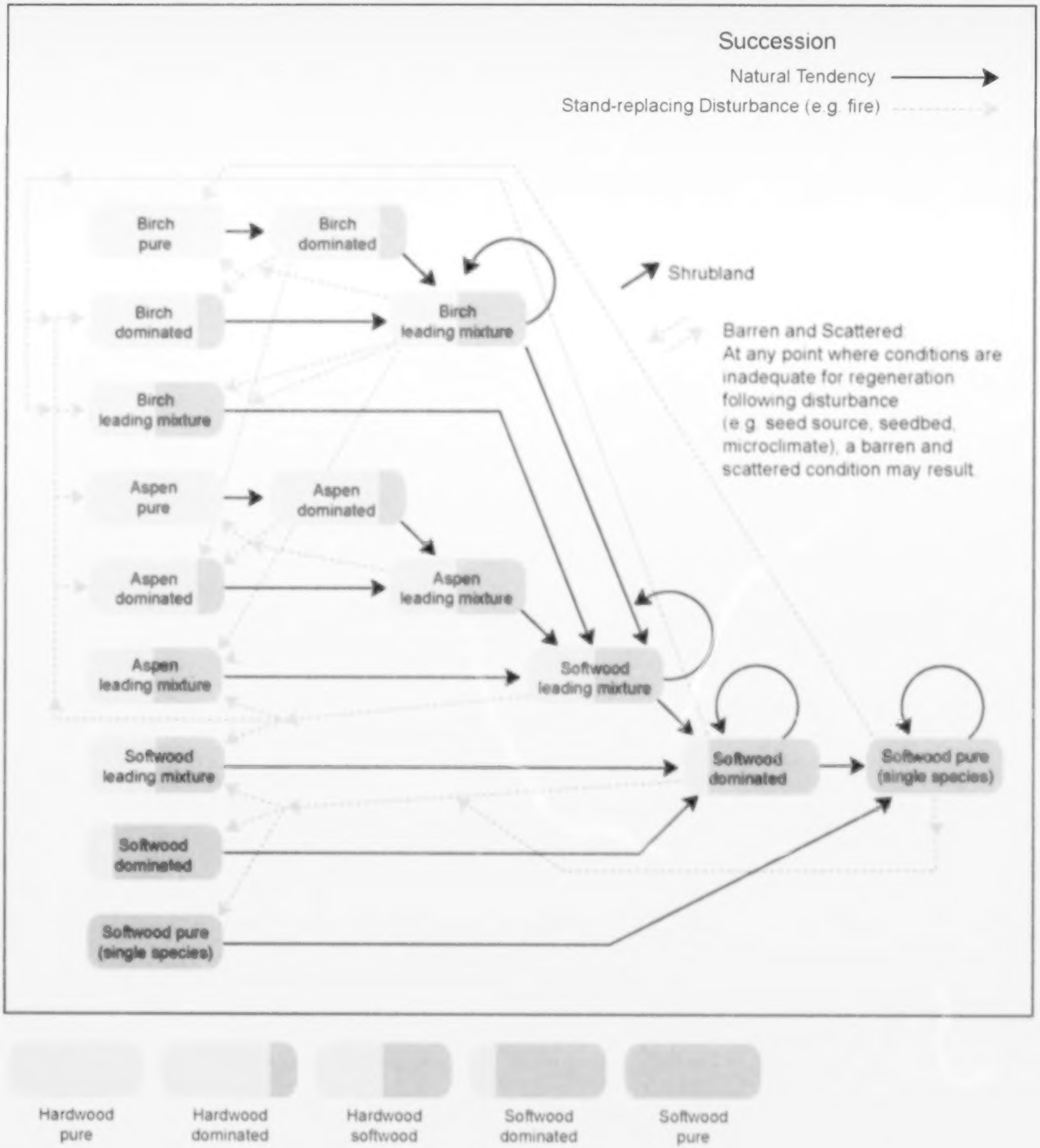
In general, suitable seedbeds and surface conditions available for regeneration are strongly reduced through the stem exclusion stage and only begin to increase as canopy gaps start to form in the canopy transition stage. The creation of substrate conditions suitable for regeneration then becomes dependent on the frequency, type, and severity of any non-stand-replacing disturbances that occur. Mineral soil seedbeds, for example, can be exposed

Figure 4. Conceptual successional pathways that may occur on boreal mixedwood sites as a result of stand-replacing disturbances (e.g. a low to moderate intensity, moderate severity fire).


Succession
Natural Tendency
Stand-replacing Disturbance (e.g. fire)
Birch pure
Birch dominated
Birch dominated
Birch leading mixture
Shrubland
Birch leading mixture
Barren and Scattered
At any point where conditions are inadequate for regeneration following disturbance (e.g. seed source, seedbed, microclimate), a barren and scattered condition may result
Aspen pure
Aspen dominated
Aspen dominated
Aspen leading mixture
Aspen leading mixture
Softwood leading mixture
Softwood leading mixture
Softwood dominated
Softwood pure (single species)
Softwood dominated
Softwood pure (single species)
Hardwood pure
Hardwood dominated
Hardwood softwood
Softwood dominated
Softwood pure

Stand-replacing disturbances can occur at any point along the successional pathway. When these occur, stands return to the initiation stage.

Figure 4. Conceptual successional pathways that may occur on boreal mixedwood sites as a result of stand-replacing disturbances (e.g. a low to moderate intensity, moderate severity fire).


Succession
Natural Tendency
Stand-replacing Disturbance (e.g. fire)
Shrubland
Barren and Scattered
At any point where conditions are inadequate for regeneration following disturbance (e.g. seed source, seedbed, microclimate), a barren and scattered condition may result
Birch pure
Birch dominated
Birch leading mixture
Aspen pure
Aspen dominated
Aspen leading mixture
Softwood leading mixture
Softwood dominated
Softwood pure (single species)
Birch dominated
Birch leading mixture
Aspen dominated
Aspen leading mixture
Softwood leading mixture
Softwood dominated
Softwood pure (single species)
Hardwood pure
Hardwood dominated
Hardwood softwood
Softwood dominated
Softwood pure

Stand-replacing disturbances can occur at any point along the successional pathway. When these occur, stands return to the initiation stage.

with windthrow but not directly as a result of insect defoliation. Likewise, the availability of well-decayed wood as a seedbed (suitable for spruce) may be dependent on inputs from windthrow or from breakage due to snow and ice damage. Warm root zone temperatures and other factors needed for the vegetative propagation of hardwoods occur only when large forest gaps are created that are free from deep duff layers and heavy vegetative competition. The relatively infrequent occurrence of these conditions contributes to the natural tendency for succession to move toward shade-tolerant conifers.

Environmental Conditions

Environmental conditions can be critical to the performance of individual trees and therefore, to community composition and stand structure. Environmental influences include regional climate, microclimate, and site quality.

Regional Climate

In the boreal forest, trends in climate are evident along geographical gradients from south-to-north and east-to-west. Along the south-to-north (latitudinal) gradient, growing seasons become shorter, air and soil temperatures are less favourable for tree growth, and soils are less productive (decomposition and nutrient cycling are slower at lower temperatures). Along the east-to-west (longitudinal) gradient, the most obvious changes are a decrease in humidity, and an increase in evapotranspiration (i.e. conditions become drier).

Generally, the productivity of boreal tree species decreases as favourable climatic conditions decrease along these geographical gradients. Although boreal tree species exhibit qualitatively similar responses to changes in climate, individual tree species may differ in the magnitude of their response. This might be sufficient in some cases to alter competitive and successional relationships across climatic regions. For example, evergreen species may have an advantage over deciduous species where the growing season is either shorter or more unpredictable (due to weather extremes).

Microclimate, site quality, and vegetative competition exert more site-specific influences on tree performance than regional climate. They vary with local differences in slope, aspect, exposure, soil parent material, soil texture, depth and type of organic matter, and associated physical, chemical, and microbial soil properties.

Microclimate

Microclimate varies with changes in vegetation and tree canopy cover which modify wind and energy input. Most individual microclimatic factors influence tree species establishment and performance primarily during the stand initiation stage when vegetation and tree canopy cover is low. Depending on the site, exposed conditions in the initiation stage may be associated with a higher frequency of frost, an increase in evaporation, and sometimes lower surface moisture retention compared to undisturbed, forested areas. Seedlings of species that are susceptible to these stresses (see Sections IV and VII) may have limited survival and growth in comparison to other species (e.g. white spruce is particularly susceptible to frost). These limitations are likely to become less important over time because harsh microclimatic conditions tend to be reduced as vegetation colonizes a site.

Light is a primary microclimatic factor driving all stages of stand development. High light conditions in the stand initiation stage favour the development of fast-growing shade-intolerant species which may overtop and shade slower growing more shade-tolerant conifers. This leads to suppression of the latter, and vertical canopy stratification may result. Eventually, as canopy trees die, light levels increase in the understorey which may then drive the transition of any understorey conifers into the canopy. Light availability continues to influence species composition and stand structure in the gap dynamics stage because the various light environments created by gaps of different sizes favour different species. Although many species can be established in relatively small gaps, only shade-tolerant species are capable of surviving for prolonged periods under these conditions. Aspen and other shade-intolerant species are generally only successful in larger gaps.

Site Quality

Site quality (soil moisture, nutrient regime, and aeration) has a direct effect on species composition and stand structure through its influence on species height growth potentials. Although stands with similar species compositions may occur on a wide range of sites, the growth of the component species may in some cases differ sufficiently to alter the successional outcome on the site. In later stages of succession, competition between tree species for water and nutrients within forest gaps may intensify on poorer quality sites.

Site quality may also impact stand development indirectly in a variety of ways. For example, vegetative competition is generally greater on moist, fertile sites than on drier, less fertile sites; and tree pathogens such as *Armillaria* spp. and *Inonotus tomentosus* occur more frequently on fresh soils than on drier or wetter soils. Tree longevity may also be affected. In general, boreal tree species grow slower and live longer on less productive sites than on more productive sites. Longevity can be particularly important in defining the canopy transition stage.

Vegetative Competition

Throughout stand development, vegetative competition can be important—inhibiting the establishment, survival, and growth of boreal tree species by occupying establishment space (covering seedbeds and preventing soil warming) and competing for light, nutrients, and water.

Tree species differ in both their susceptibility and response to vegetative competition. On productive boreal mixedwood sites, it is unlikely that other vegetation will overtop rapidly growing aspen and birch suckers and sprouts when both establish simultaneously. More vulnerable to overtopping are tree species that are established from seed and those with inherently slow initial height growth rates. Suppressed tree seedlings may or may not survive. Shade tolerance influences the ability of a species to survive in a competitive environment. However, dense shrub layers (e.g. mountain maple and beaked hazel) can sometimes competitively exclude even the most shade-tolerant conifers.

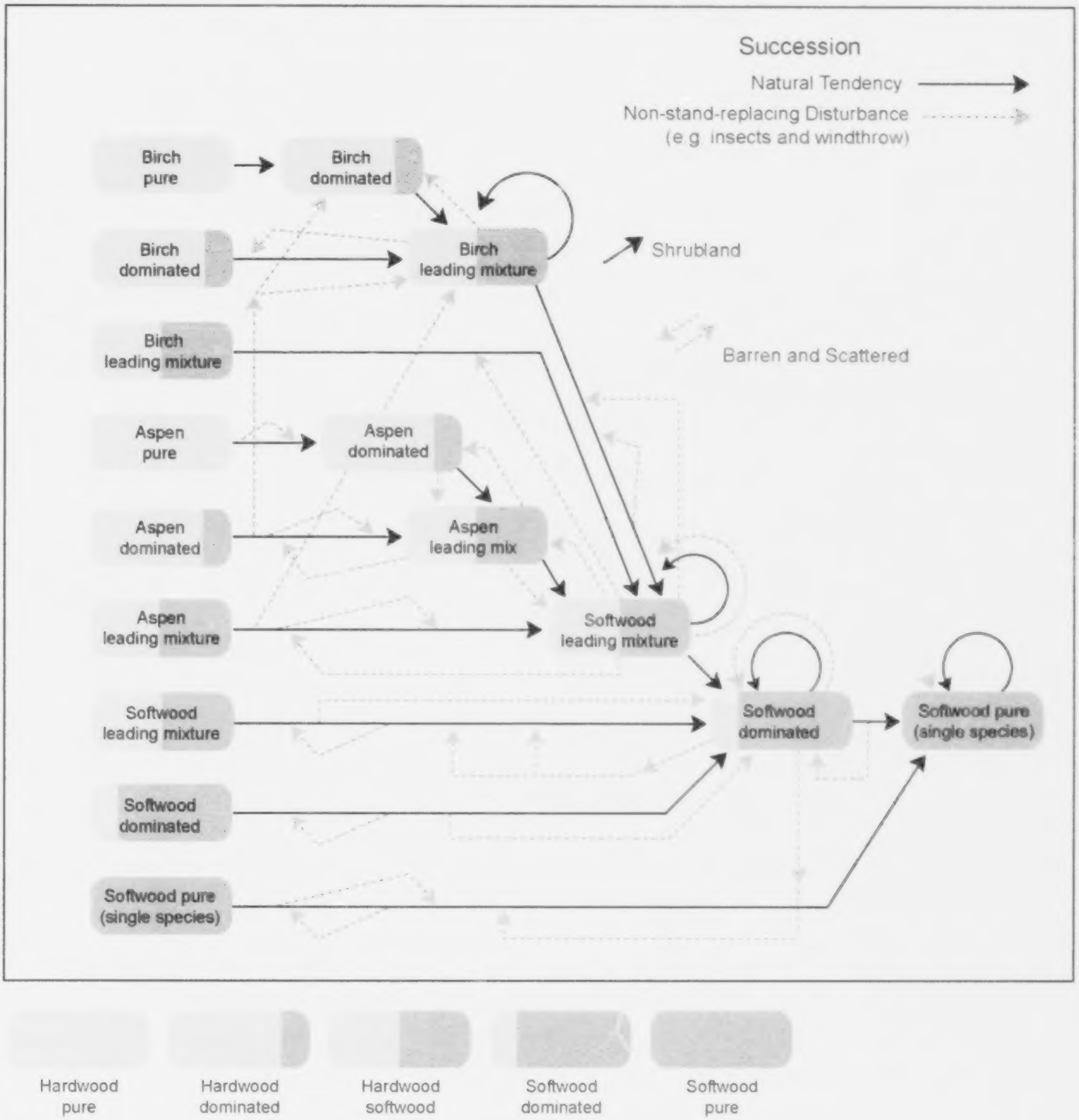
Non-stand-replacing Disturbances

An initial stand-replacing disturbance generally has the greatest impact on tree species composition and stand structure throughout stand development. However, as the stand develops, non-stand-replacing disturbances caused by: insects; disease; herbivory; wind, snow, and ice damage; and non-catastrophic fire may alter successional pathways. When non-stand-replacing disturbances do occur, susceptible tree species are affected either as individuals or in groups. Subsequent mortality of overstorey trees (rather than just poor growth) can lead to the formation of different sized canopy gaps. These gaps may increase understorey light levels enough to release conifers and/or to support new trees capable of becoming established under the altered conditions (in accordance with species-specific substrate, light, water, and nutrient requirements).

The impact of non-stand-replacing disturbances can alter the direction and speed of stand development. Depending on the nature of the disturbance, a stand could be set back to an earlier successional stage, or accelerated to a later successional stage (Figure 5). In general, disturbances that affect mostly hardwood species (e.g. forest tent caterpillar [*Malacosoma disstria*]) tend to accelerate the transition to conifers, whereas disturbances that affect mostly conifers (e.g. eastern spruce budworm) may return the stand to an earlier successional stage.

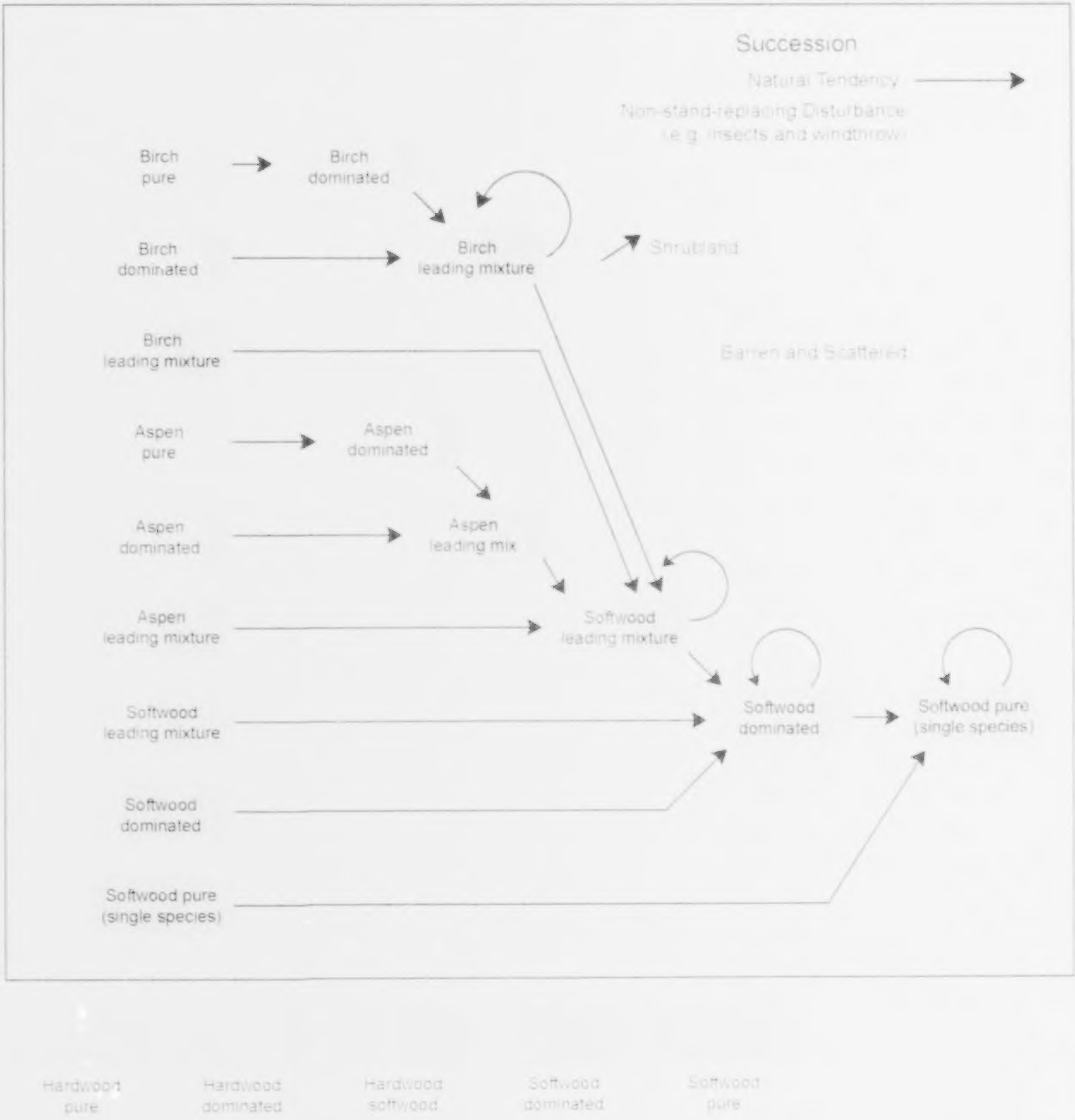
Given that non-stand-replacing disturbances are largely random, the susceptibility of stands to these events is more apparent than the frequency of these events. For example, susceptibility to both windthrow and non-stand-replacing fires is likely to increase during stand development as tree height and fuel loading increases and tree stability decreases. Both types of disturbance are less likely to occur at the stand initiation stage when trees are shorter. Non-stand-replacing disturbances tend to play a larger role in moister, more easterly regions of the boreal forest where the cycle for catastrophic (stand-replacing) fire is longer than in the warmer, drier, more southwesterly regions. Longer fire cycles allow more time for other types of disturbances to influence species composition and stand structure. The susceptibility of boreal tree species to specific types of non-stand-replacing disturbances, and the types of effects that specific non-stand-replacing disturbances can have on stand development, are discussed in detail in Section IV.

Figure 5. Conceptual successional pathways that may occur on boreal mixedwood sites resulting from non-stand-replacing disturbances.


Succession
Natural Tendency
Non-stand-replacing Disturbance (e.g. insects and windthrow)
Birch pure
Birch dominated
Birch dominated
Birch leading mixture
Birch leading mixture
Shrubland
Barren and Scattered
Aspen pure
Aspen dominated
Aspen dominated
Aspen leading mix
Aspen leading mixture
Softwood leading mixture
Softwood leading mixture
Softwood dominated
Softwood dominated
Softwood pure (single species)
Softwood pure (single species)
Hardwood pure
Hardwood dominated
Hardwood softwood
Softwood dominated
Softwood pure

Note that non-stand-replacing disturbances can disrupt the directional changes in overstorey tree species composition that otherwise tend to occur naturally. Stands can be accelerated to later developmental stages or set back to earlier developmental stages depending on the nature of the disturbance and the recruitment, survival, and growth of understorey trees.

Figure 5. Conceptual successional pathways that may occur on boreal mixedwood sites resulting from non-stand-replacing disturbances


Succession
Natural Tendency
Non-stand-replacing Disturbance
(i.e.g. insects and windthrow)
Birch pure
Birch dominated
Birch dominated
Birch leading mixture
Shrubland
Birch leading mixture
Barren and Scattered
Aspen pure
Aspen dominated
Aspen dominated
Aspen leading mix
Aspen leading mixture
Softwood leading mixture
Softwood leading mixture
Softwood dominated
Softwood pure (single species)
Softwood dominated
Softwood pure (single species)
Hardwood pure
Hardwood dominated
Hardwood softwood
Softwood dominated
Softwood pure

Note that non-stand-replacing disturbances can disrupt the directional changes in overstorey tree species composition that otherwise tend to occur naturally. Stands can be accelerated to later developmental stages or set back to earlier developmental stages depending on the nature of the disturbance and the recruitment, survival, and growth of understorey trees.

SECTION III – SILVICULTURAL PRACTICES

Section III outlines the silvicultural systems applicable to boreal mixedwood management in Ontario and describes the associated silvicultural methods and treatments. Silvicultural terms are provided in the glossary.

SILVICULTURAL TERMS AND DEFINITIONS

Where applicable, silvicultural terms and definitions are consistent with traditional silvicultural references: *The Practice of Silviculture* (Smith *et al.* 1997), *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996), and *Silvicultural Terms in Canada* (NRC 1995). However, boreal mixedwood silviculture includes many recently developed, non-traditional strategies and tactics and therefore, has its own set of unique terminology not previously referenced in Ontario. Where traditional terminology is not applicable, silvicultural terms have been established for application in the boreal forest of Ontario.

SILVICULTURE IN ONTARIO

Silviculture is the art, science, and practice of controlling the establishment, composition, health, quality, and growth of forest stands to achieve the objectives of management (NRC 1995, Dunster and Dunster 1996). Oliver and Larson (1990) further describe the term as the manipulation of forest stands through timber harvest, forest renewal, and maintenance of the new forest.

The foundation of silviculture is the autecology and synecology of tree species. Autecology is the study of the response and adaptation of individual organisms or species to their environment (Barbour *et al.* 1987). Synecology is the study of groups of organisms and their interaction in relation to environmental conditions (Dunster and Dunster 1996, Helms 1998).

Silvicultural interventions are applied to move a stand from its current condition to a desired future condition. The desired future stand condition may be described in terms of species composition and structure. The future condition is designed to contribute to the achievement of forest level objectives such as timber production, the provision and maintenance of wildlife habitat, landscape diversity, recreational values, and genetic diversity.

MIXEDWOOD SILVICULTURE

Boreal mixedwood management recommends site-specific and species-specific silvicultural treatments based, whenever possible, on the emulation of natural disturbances and processes. The application of ecologically appropriate, silviculturally feasible, and economically viable boreal mixedwood silvicultural treatments involves consideration of the following factors:

- current stand condition
- desired future stand condition
- natural successional patterns and tendencies
- the ability of the proposed silvicultural treatment to maintain or enhance stem, stand, or site quality and long-term site productivity
- the reliability of the silvicultural treatment to successfully secure the desired future stand condition

Silvicultural treatments relevant to each of the stand development stages are presented in Table 1. This table may assist with the selection of appropriate silvicultural treatments for each stage of stand development. Figure 1 illustrates silvicultural treatment symbols that are used in the figures throughout Section III.

SILVICULTURAL SYSTEMS AND HARVEST METHODS

A silvicultural system is a planned program of silvicultural treatments that extends throughout the life of a stand for the purpose of controlling stand establishment, composition, and growth, and includes a harvest method as well as any tending methods (Smith *et al.* 1997). Silvicultural systems are classified according to the method of harvesting with a view to regeneration (OMNR 1996). They are divided into several categories in a hierarchical system and grouped, at the highest level, according to whether

Table 1. Silvicultural treatments applied at different stages of stand development.

Stand Development Stage	Silvicultural Treatment	Section III Page Number
Stand Initiation	Renewal	22
	Cleaning	34
	Supplemental Regeneration	33
	Compositional Treatment (CpT)	37
	Juvenile Spacing	37
	Reinitiation	33
Stem Exclusion	Renewal	22
	Cleaning	34
	Pre-commercial Thinning (PCT)	37
	Liberation Treatment (LT)	37
	Commercial Thinning (CT)	40
	Compositional Treatment (CpT)	37
	Harvest	1
Canopy Transition	Renewal	22
	Cleaning	34
	Harvest	1
Gap Dynamics	Renewal	22
	Cleaning	34
	Harvest	1

the intent is to promote an even-aged or an uneven-aged forest. Even-aged systems generally create stands where the trees are approximately the same age, or within one age class. Uneven-aged systems result in future stand conditions where there are at least three cohorts of individuals each representing a different age class (Smith *et al.* 1997).

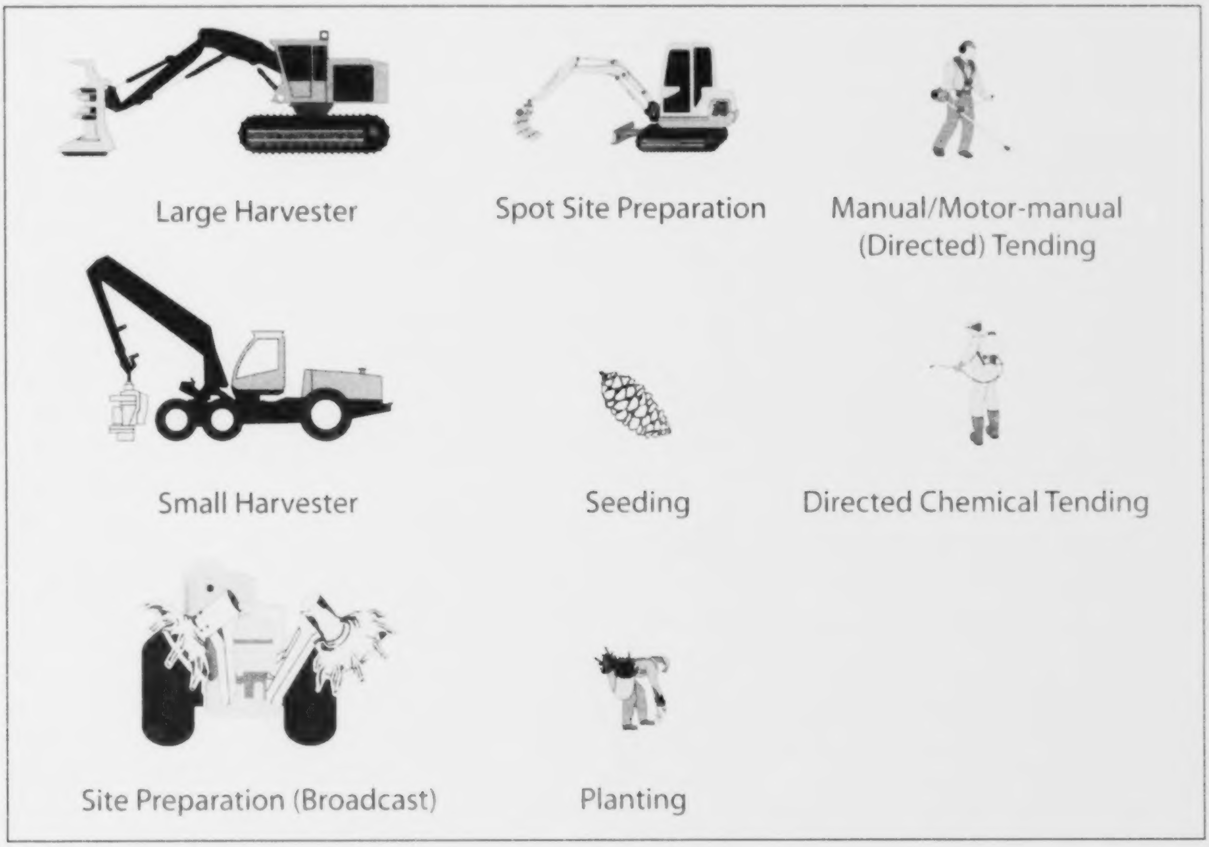
The silvicultural systems applicable to boreal mixedwood management are: clearcut, shelterwood, and selection. All of these systems are currently used in Ontario, although shelterwood and selection systems have been most commonly associated with the management of the Great Lakes–St. Lawrence forest stand conditions. The harvest method associated with each silvicultural system determines the pattern, timing, and degree of canopy removal. Figure 2 illustrates the harvest and regeneration methods associated with these silvicultural systems.

Selecting a Silvicultural System

Factors to consider when choosing a silvicultural system include:

- silvics of the species of interest
- reproductive habits of competing species
- the natural disturbance regime
- potential insect and disease hazards
- potential environmental hazards (e.g. frost; risk of wind, snow, or ice damage)
- the size, age, and vigour of the trees in the current stand and overall stand condition as affected by site and environmental factors
- genetics of tree species
- wildlife requirements
- aesthetics and recreational values

Figure 1. Silvicultural treatment symbols used in Section III.



Large Harvester

Spot Site Preparation

Manual/Motor-manual (Directed) Tending

Small Harvester

Seeding

Directed Chemical Tending

Site Preparation (Broadcast)

Planting

- social and cultural values
- management objectives and constraints

The final selection of a silvicultural system involves the analysis and consideration of all the site-, stand-, and landscape-scale factors that may influence the manager's ability to successfully secure the desired future stand condition and meet management objectives.

Selecting a Harvest Method

Factors that influence the choice of harvest method include (Dey and MacDonald 2001):

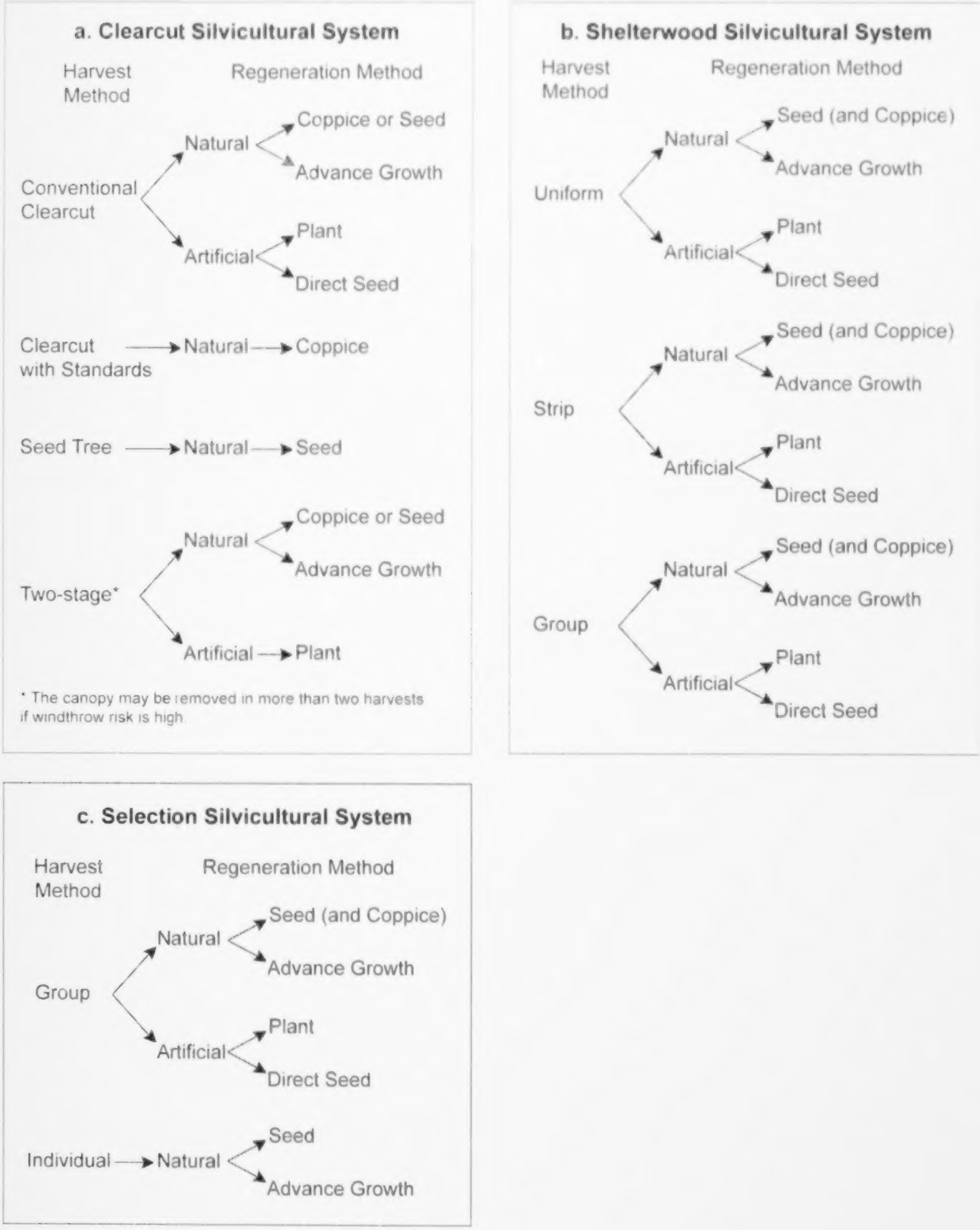
- microclimate (particularly light) as affected by the shape, size, and orientation of canopy openings
- silvics of species of interest
- presence, abundance, and size of advance growth of desired species
- presence of seed trees of desired species
- seed dispersal potential
- potential for competition from undesired vegetation

The Clearcut System

The clearcut system typically involves the removal of most or all of the merchantable trees from a stand in one operation and the subsequent regeneration of an even-aged stand with minimum structural complexity in which new seedlings become established in a fully exposed microclimate (NRC 1995). The clearcut system relies on the use of either natural or artificial regeneration.

Note: In this instance, "one operation" refers to a silvicultural context rather than timing of harvest. It implies that the overstorey is removed over a short

Figure 2. Silvicultural systems and associated harvest and regeneration methods: a) clearcut, b) shelterwood, and c) selection.


a. Clearcut Silvicultural System
Harvest Method
Regeneration Method
Conventional Clearcut
Natural
Coppice or Seed
Advance Growth
Artificial
Plant
Direct Seed
Clearcut with Standards
Natural
Coppice
Seed Tree
Natural
Seed
Two-stage*
Natural
Coppice or Seed
Advance Growth
Artificial
Plant
b. Shelterwood Silvicultural System
Harvest Method
Regeneration Method
Uniform
Natural
Seed (and Coppice)
Advance Growth
Artificial
Plant
Direct Seed
Strip
Natural
Seed (and Coppice)
Advance Growth
Artificial
Plant
Direct Seed
Group
Natural
Seed (and Coppice)
Advance Growth
Artificial
Plant
Direct Seed
c. Selection Silvicultural System
Harvest Method
Regeneration Method
Group
Natural
Seed (and Coppice)
Advance Growth
Artificial
Plant
Direct Seed
Individual
Natural
Seed
Advance Growth

* The canopy may be removed in more than two harvests if windthrow risk is high.

time period rather than in a planned sequence of removals over many years.

Clearcut Harvest Methods

The different harvest methods that may be used in association with the clearcut system include:

- conventional clearcut
- clearcut with standards
- two-stage harvesting
- seed tree

Conventional Clearcut

The conventional clearcut involves the removal of most or all trees from a stand (or a number of adjacent stands). This approach results in an even-aged stand with minimal structural complexity. Regeneration develops in a fully exposed micro-climate.

Clearcut with Standards

This harvest method involves the removal of most aspen stems but retains 20 to 25 scattered aspen stems per hectare. It is based on the biology of aspen root suckering, and attempts to reduce the proliferation of aspen root suckers that occur after clearcutting (Ruark 1990). In addition, it may improve the quality of aspen vegetative regeneration in the future stand.

Two-stage

This harvest method consists of two harvests usually aimed at softwood and hardwood production on the same site (Navratil *et al.* 1994) (Figure 3). This approach is applied to a distinctly two-tiered stand and emphasizes the protection of near-merchantable (e.g. 10 to 15 centimetre diameter breast height [dbh]) understorey conifer stems in the intermediate crown class and sometimes other smaller advance growth.

Two-stage harvesting involves:

- careful removal of intolerant hardwood or conifer overstorey
- protection of large advance growth
- a quick return of a stand to the stem exclusion stage due to the well-developed understorey

Released conifers that were in the intermediate crown class are more susceptible to windthrow following the removal of the main canopy when the slenderness coefficient of the residual stems is greater than or equal to 100 (see Wind Damage, Section IV). The canopy may be removed in more than two harvests if windfirmness is a concern (Navratil *et al.* 1994).

Seed Tree

The seed tree harvest method involves the removal of all trees from an area except for a relatively small number of seed trees of desired quality left singly, in small groups, or in strips for regeneration purposes. The seed tree method requires an adequate seed source, regular seed production, effective seed dispersal, and a well distributed receptive seedbed. With most boreal mixedwood conifer species, one or two good seed crops can usually be expected within any given five year period (OMNR 1977, Greene *et al.* 2000, 2002). Seed trees may be removed after regeneration has been established.

Dominant or super-canopy or emergent trees in the main canopy should be considered as seed trees since they are generally more windfirm. To reduce windthrow and maximize seed dispersal, seed trees can be positioned at the upwind border of the cutblock (Navratil *et al.* 1994). Leaving groups of seed trees also reduces the risk of windthrow.

Spatial Variations of Clearcut Harvest Methods

Spatial variations that can be applied within each of the clearcut harvest methods include strip, block, and patch cutting.

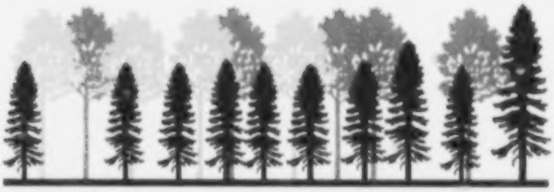
Strip Cutting

Strip cutting involves the removal of trees in alternate or progressive strips. Strip cutting is most often prescribed to encourage natural regeneration and to protect fragile sites. Consideration must be given to (Smith *et al.* 1997):

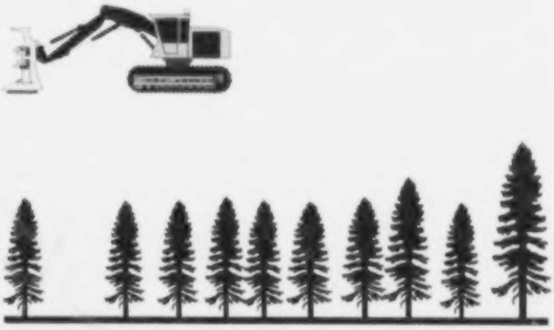
- strip width, which should be from two to six times the height of the adjacent trees from which the seed will be obtained (Groot *et al.* 1997)

Figure 3. Two-stage harvest in an aspen dominated mixture.

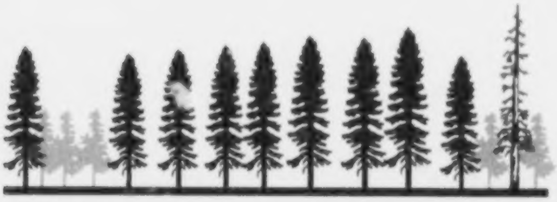
1st Stage



a. The hardwood overstorey is removed carefully.

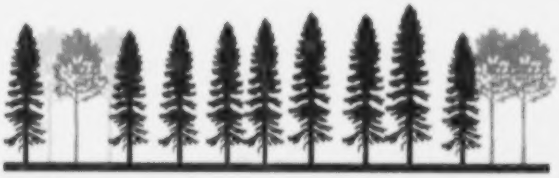


b. This results in the release of the understorey conifer.

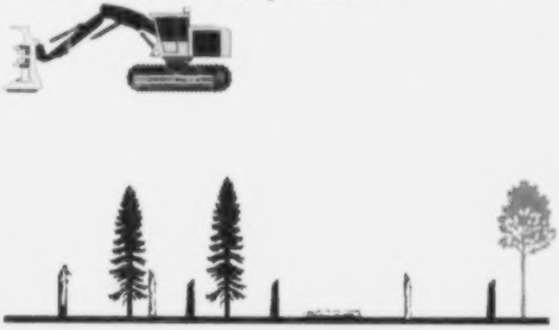


c. With time, the residual conifers form the overstorey, with hardwood regeneration occurring in some of the openings.

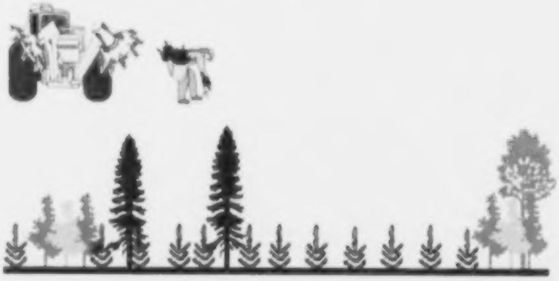
2nd Stage



d. Eventually, the hardwoods will grow fast enough to create a conifer leading condition.



e. This can then be clearcut.



f. The site can then be site prepared and planted to initiate a new stand.

- strip orientation, which should be perpendicular to the prevailing wind direction to secure maximum seed dispersal and reduce the risk of wind damage

Block Cutting

Block cutting involves the removal of trees, usually in a checkerboard pattern, with blocks of uncut timber separating the harvest blocks. Block width is determined by site and seed dispersal considerations similar to those identified with strip cutting (Jeglum and Kennington 1993). Individual blocks rarely exceed 10 hectares.

Patch Cutting

Patch cutting involves the removal of stands in irregularly-shaped harvest areas. Patch cuts are well suited to harvesting in broken terrain or in stands that lack uniformity. Patch configurations are often a reflection of the mosaic in the original forest and can vary greatly in size. Some boreal species are more easily regenerated in small patch cuts than in large clearcuts (Vincent 1965). Patch cuts may:

- provide a higher edge-to-area ratio than block cuts (Chapeskie *et al.* 1989)
- maximize natural regeneration from adjacent seed sources

The Shelterwood System

The shelterwood system involves the removal of the overstorey in stages for the purpose of securing natural or artificial regeneration under the shelter of the residual trees. The degree of residual crown cover and the species composition of residual overstorey trees may be modified to encourage or discourage establishment and development of particular species.

Residual overstorey trees should be of high-quality, desirable species as these individuals will provide seed for regeneration. Trees should be windfirm and harvest operations should be planned to avoid damage to residual trees. Residual trees will increase in size and value during the reproduction phase and can be removed as required to release established regeneration.

The shelterwood system is implemented by using a series of harvest entries, each with specific objectives and characteristics:

- one or several preparatory cuts may be undertaken to improve the vigour of prospective seed-bearing trees
- a seed or regeneration cut is then undertaken to remove 30 to 70 percent of the canopy, depending upon the microclimate requirements of the target and acceptable tree species and competing vegetation (understorey vegetation management is often required on boreal mixedwood sites)
- one or more subsequent removal cuts may then be used to release well-established regeneration from overstorey shade
- a final cut occurs that removes most or all of the remaining canopy, providing full sunlight to the established regeneration

Shelterwood Harvest Methods

Shelterwood harvest methods presently used in Ontario include uniform, strip, and group arrangements.

Uniform Shelterwood

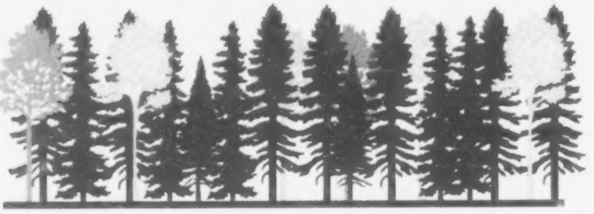
In a uniform shelterwood arrangement, the entire stand is harvested throughout to obtain a uniform level of overstorey shelter (Figure 4).

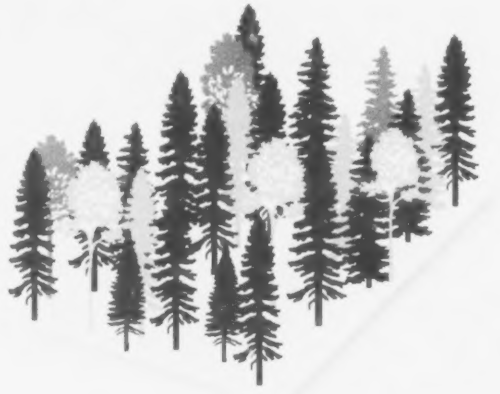
Strip Shelterwood

A strip shelterwood arrangement involves the progressive harvesting of a stand using a series of strip cuts in one of two patterns. Strips may be cut entirely clear as long as shelter and seed can be provided from the adjacent uncut strips (Figure 5). Sheltering trees can also be left within the harvested strips during the seed and initial removal cuts (Figure 6).

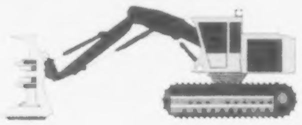
Strips are generally cut perpendicular to the direction of the prevailing wind (to reduce the risk of wind damage) and advance progressively throughout a stand over the regeneration period (Smith 1986, Navratil 1995, Flesch and Wilson 1998). Strip width is species-dependent, being wider for less shade-tolerant species, but must be narrow enough to provide shelter and seed from the residual overstorey trees. Strip widths should not exceed two tree heights (Groot *et al.* 1997).

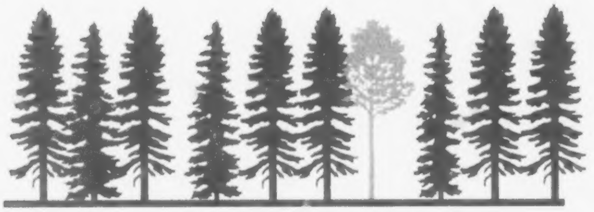
Figure 4. Uniform shelterwood harvest in a softwood leading mixture.

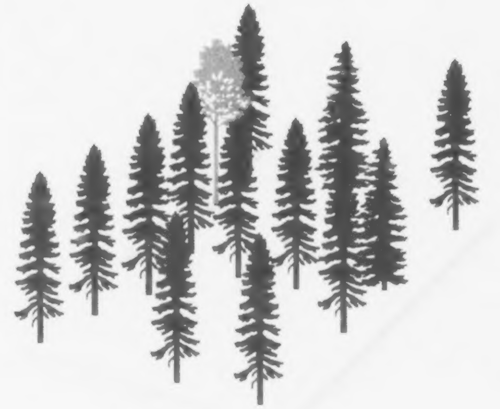




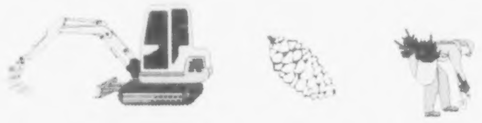
a. A softwood leading stand is harvested carefully.

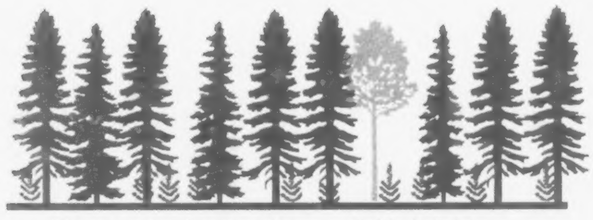


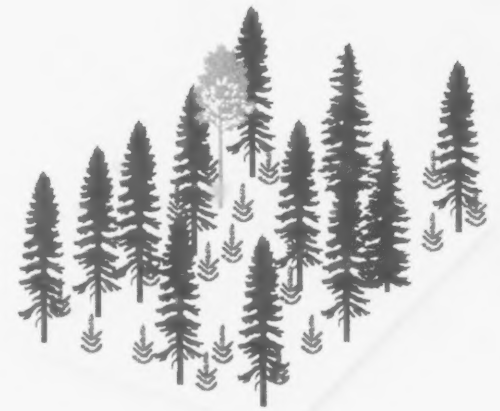




b. An overstorey dominated by appropriately spaced, dominant and co-dominant vigorous stems that provide seed and/or shelter to the natural or planted regeneration.







c. The regeneration reaches a suitable height.

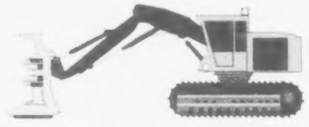
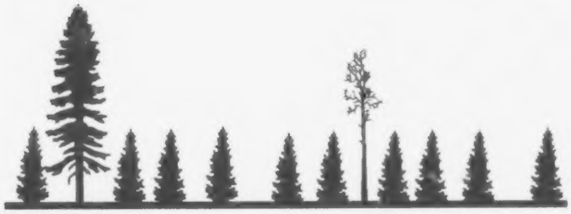
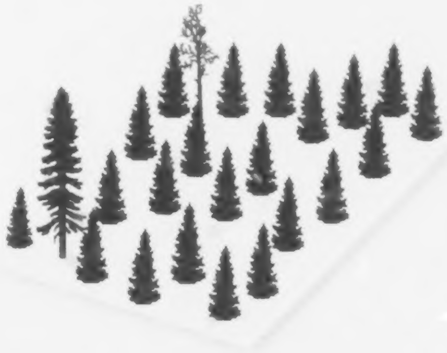
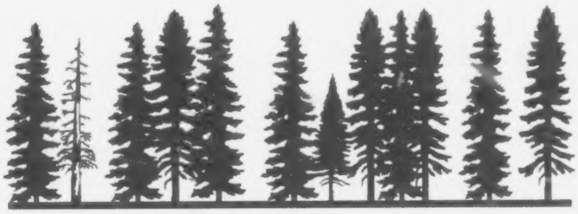


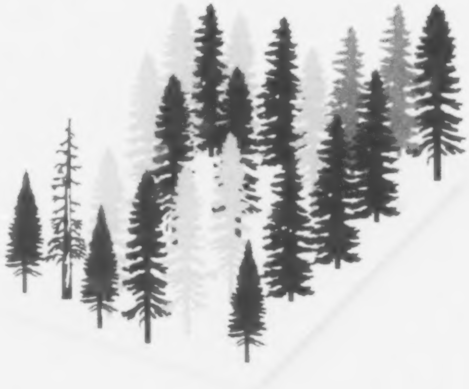
Figure 4 (cont.).





d. The overstorey is harvested to allow full sunlight to the new stand.





e. The new even-aged stand will continue to develop.

Figure 5. Strip shelterwood harvest in a birch leading mixture with shelter provided from adjacent strips.

This series of diagrams shows that:

1. The strips are oriented perpendicular to the direction of the prevailing wind.
2. The first strip is cut from the most sheltered edge of the block; subsequent strips are cut parallel to the first, but "into the wind".
3. Site preparation is required for natural regeneration of birch.

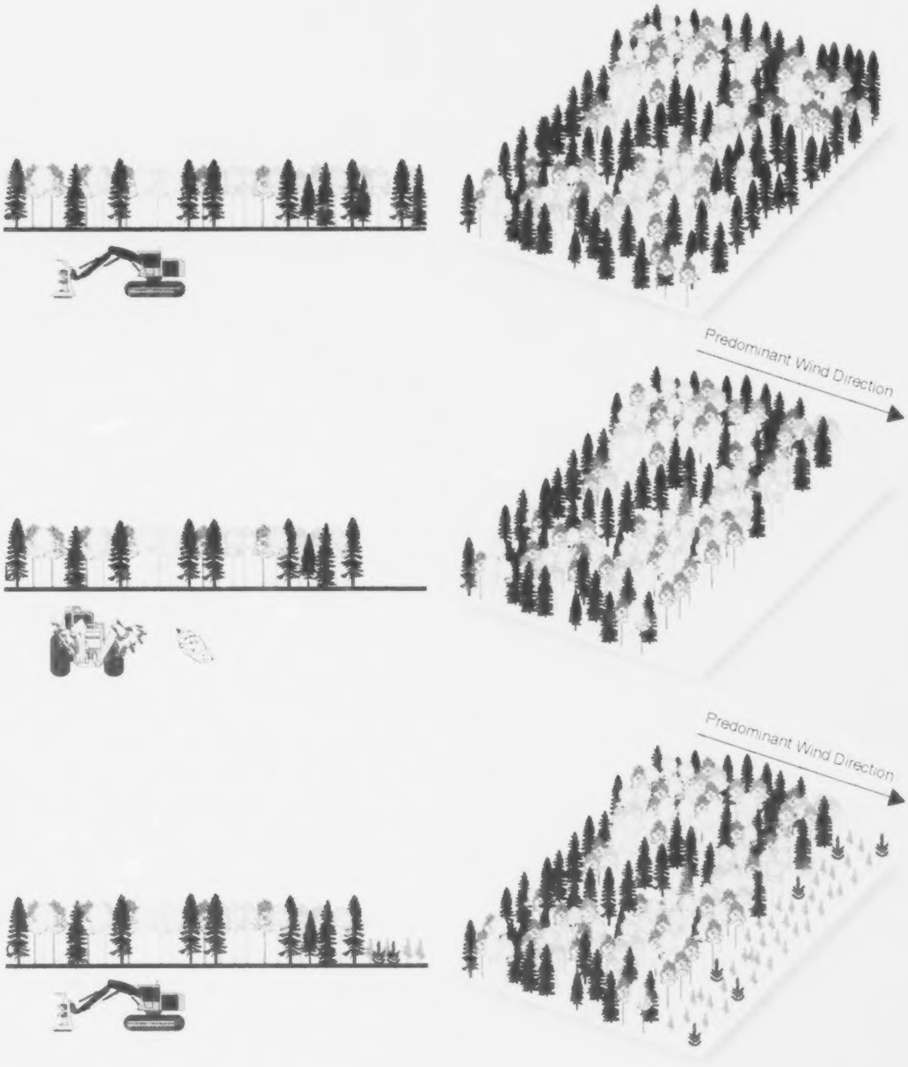


Figure 5 (cont.).

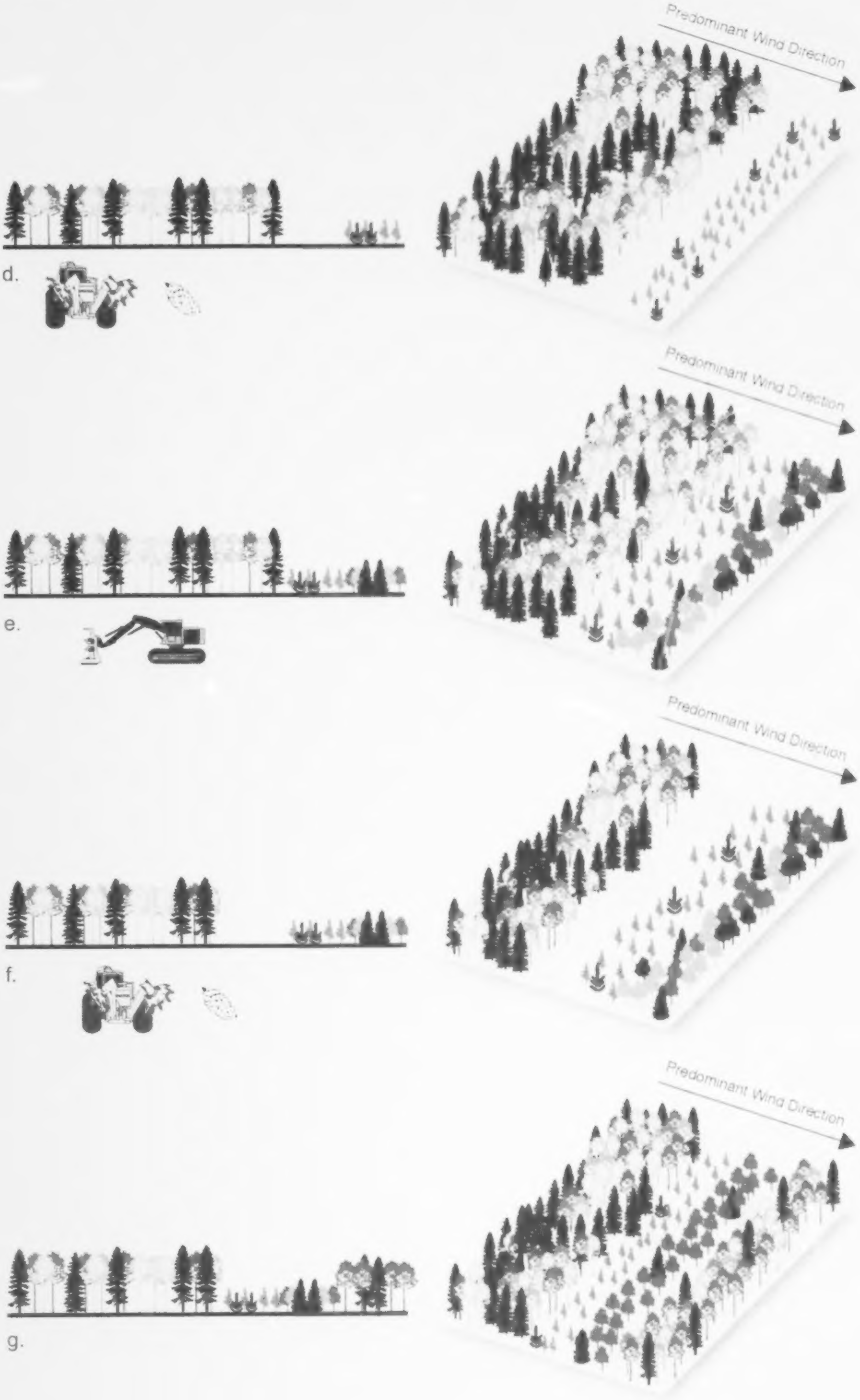

Predominant Wind Direction
d.
Predominant Wind Direction
e.
Predominant Wind Direction
f.
Predominant Wind Direction
g.

Figure 6. Strip shelterwood harvest in a softwood leading mixture with shelter provided by trees left within harvested strips.

This series of diagrams shows that:

1. Residual shelter trees are left within the cut strips.
2. Planting and tending of conifer regeneration may be required.
3. As in Figure 5, strips are cut from the "back" of the block first, then sequentially, parallel to the first strip and into the wind.

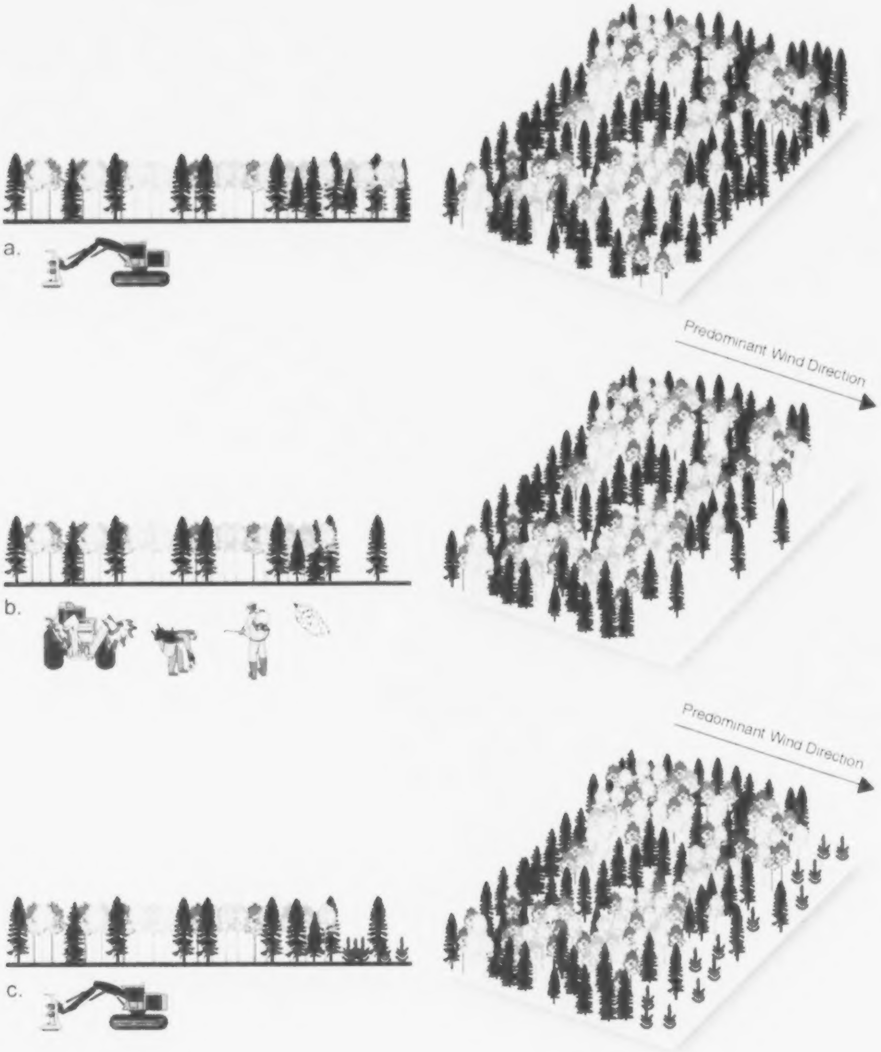
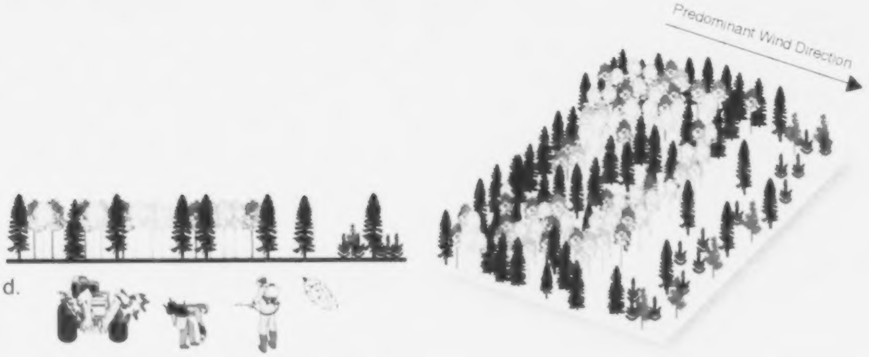

a.
Predominant Wind Direction
b.
Predominant Wind Direction
c.

Figure 6 (cont.).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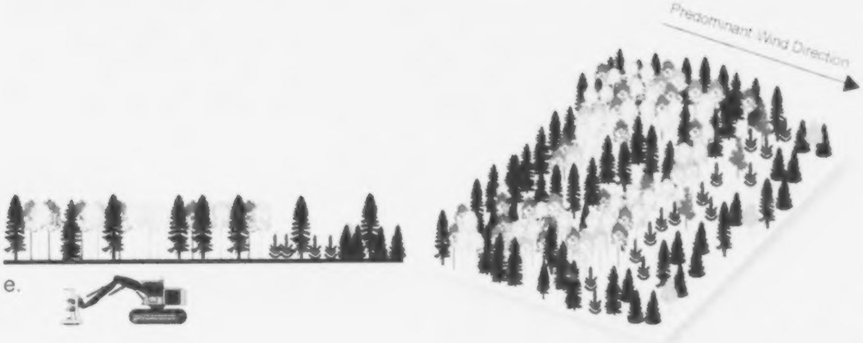
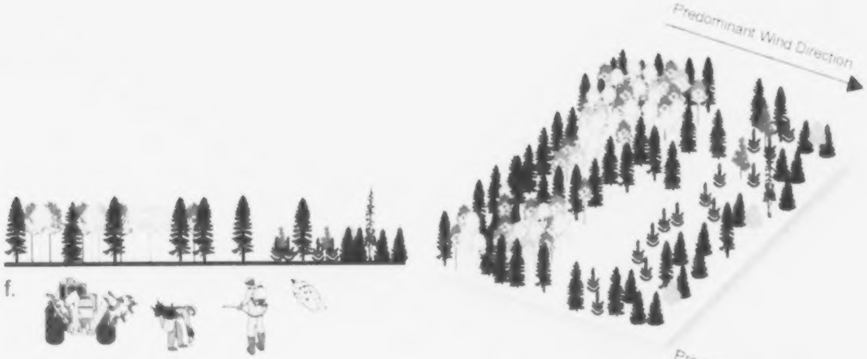
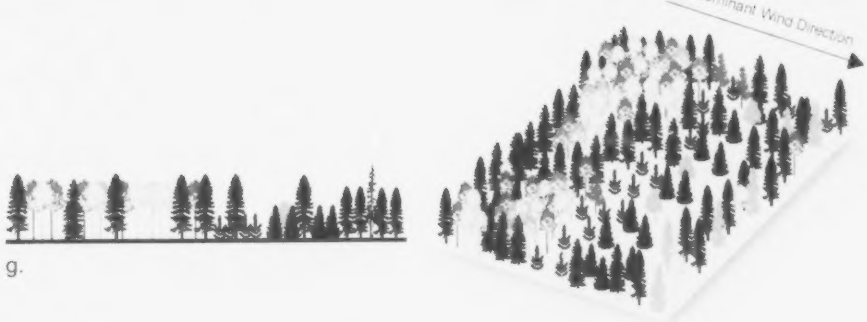

Predominant Wind Direction

e.


Predominant Wind Direction

f.


Predominant Wind Direction

g.

Group Shelterwood

The group shelterwood method involves the progressive opening of the stand in small gaps (one to two tree heights in diameter) (Figure 7). This method could be useful to secure natural regeneration in stands that are heterogeneous in composition. Shelter may be provided by overstorey trees or from adjacent standing trees.

The Selection System

The selection system involves the continual creation or maintenance of uneven-aged stands by occasional replacement of single trees or small groups of trees from a variety of diameter classes with regeneration from any source (Smith *et al.* 1997).

Aspects of this system are applicable to specific situations in boreal mixedwood management. These specifics include only a few species (e.g. balsam fir and spruce) and some stand structures or ages (e.g. beyond normal rotation age). Section VI indicates the specific situations where selection silviculture may be appropriate for consideration. In these situations, the selection system has been denoted as a developmental treatment. Under the developmental designation, the selection system could be applied as part of a successional sequence, rather than continuously in order to learn more about its applicability in specific situations. Stands should not be kept in a selection system indefinitely since repeated partial harvesting can increase the risk of volume losses due to (Harvey *et al.* 2002):

- stem and root damage from repeated stand entry
- insect and disease damage
- windthrow and natural mortality

Considerations for use of the selection system in boreal mixedwood management include:

- careful logging practices, including appropriate choice of logging and site preparation equipment to minimize damage to residual trees and regeneration (OMNR 1998b)
- damage to the physical environment and the root systems of shallow-rooted species from rutting and compaction due to repeated stand entry must be minimized

The selection system:

- usually relies on natural regeneration from seed or advance growth
- provides a continuous overstorey influence on the understorey microclimate due to the continuous presence of a substantial residual overstorey; the growth of any regeneration in the understorey will be less than that in a more open environment
- maximizes stand structural complexity
- emulates small-scale natural disturbances (e.g. small-scale windthrow and insect damage)
- reduces risk of wind damage and windthrow (Navratil 1995)
- can be used for enhanced management areas and to promote wildlife habitat
- can produce high-quality products through a representation of all diameter classes (ultimately all age classes) distributed throughout the stand (OMNR 1998a)

Selection Harvest Methods

Two different harvest methods may be used in association with the selection system: individual and group arrangements.

Individual (Single-tree) Selection

Individual selection involves the removal of single mature trees from a range of diameter classes (Smith *et al.* 1997) (Figure 8). Post-harvest understorey light levels are only slightly and temporarily increased compared to that of undisturbed stands. Competing vegetation is usually inhibited by low light conditions and other microclimatic characteristics associated with a dense overstorey (Dey and MacDonald 2001).

Group Selection

Group selection involves removing groups of trees (Figure 9) to create openings of different sizes and shapes (e.g. circular or rectangular) (NRC 1995, Smith *et al.* 1997). Group openings are less than two tree heights in diameter, which is less than that of small clearcuts (Smith *et al.* 1997, Dey and MacDonald 2001). With group selection, the understorey light regime is sometimes modified sufficiently that natural regeneration of shade-

Figure 7. Group shelterwood harvest in a softwood leading mixture.

This series of diagrams shows that:

1. The group shelterwood system results in gaps of one to two tree heights in diameter.
2. Both shelter and seed are provided by the surrounding trees on the gap perimeter.
3. The harvesting is allocated over time.

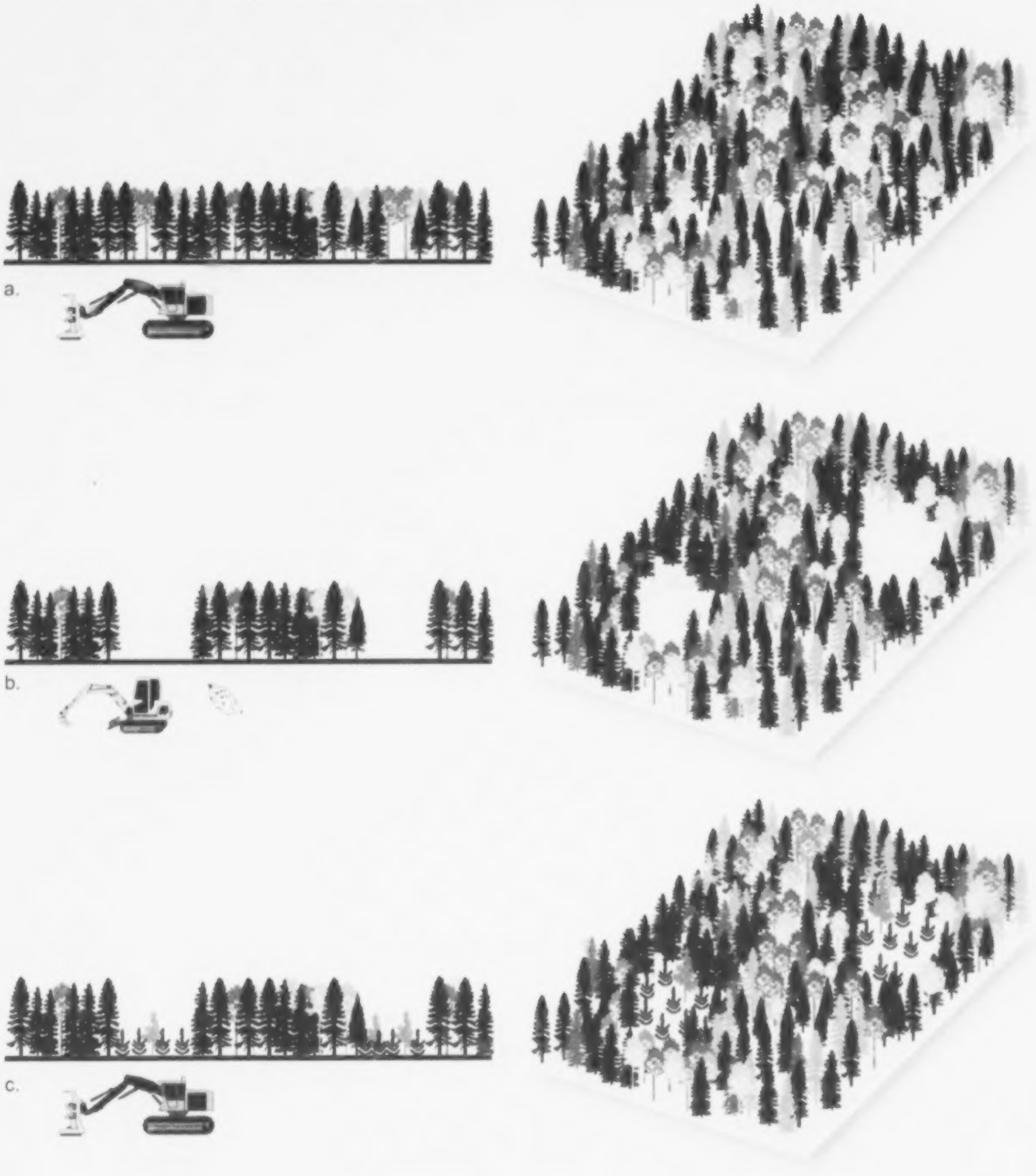


Figure 7 (cont.).

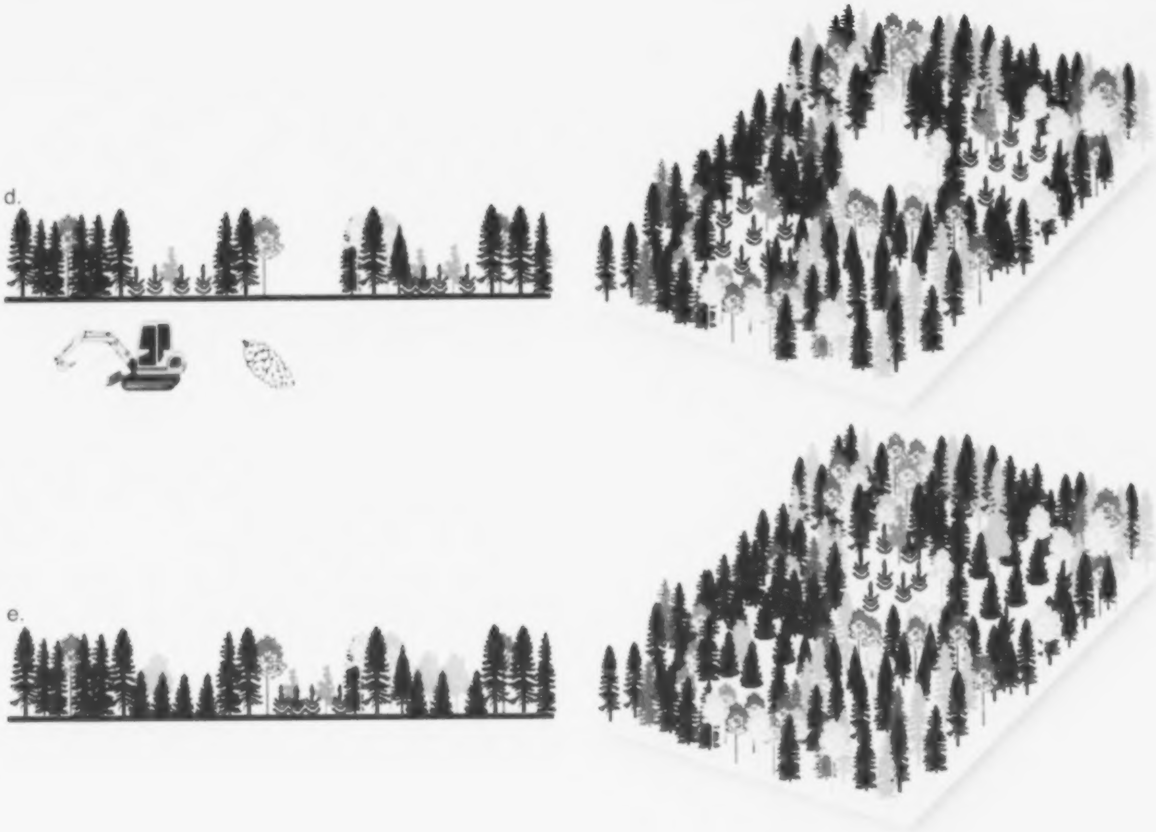


Figure 8. Individual selection harvest in a softwood dominated mixture.

This series of diagrams shows that:

1. Individual dominant and co-dominant trees are selected for removal.
2. Regeneration occurring in the small gaps is from surrounding trees.
3. A series of partial harvests occur over time.
4. The result is an uneven-aged stand structure.

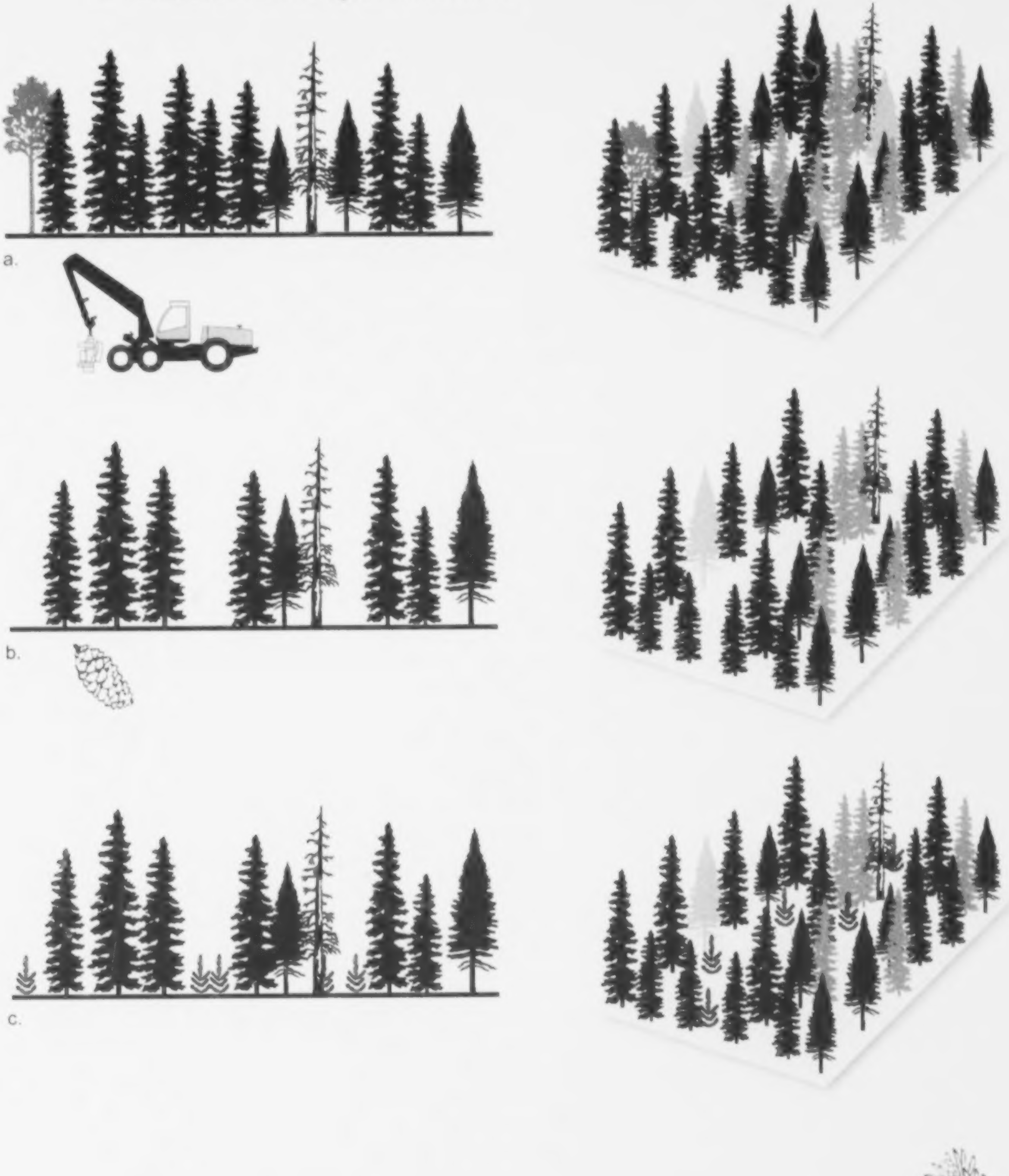


Figure 8 (cont.).

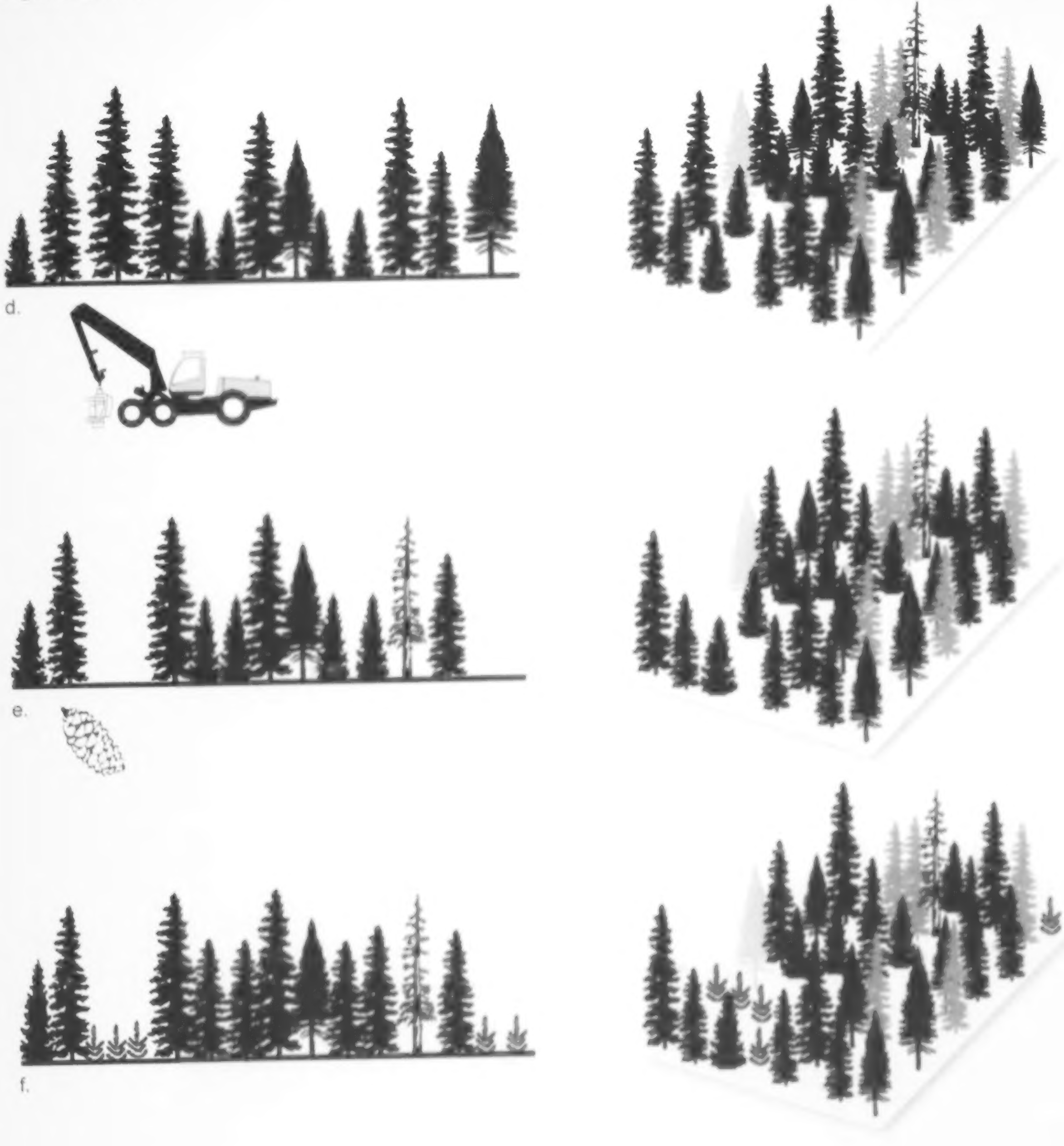


Figure 9. Group selection as applied to a softwood dominated mixture.

This series of diagrams shows that:

1. Groups of dominant and co-dominant trees are removed in gaps less than two tree heights in diameter (or equivalent area if opening is an irregular shape).
2. Natural regeneration from surrounding trees fills the gaps.
3. The group selection method employs partial harvests over time.
4. It results in an uneven-aged stand structure.

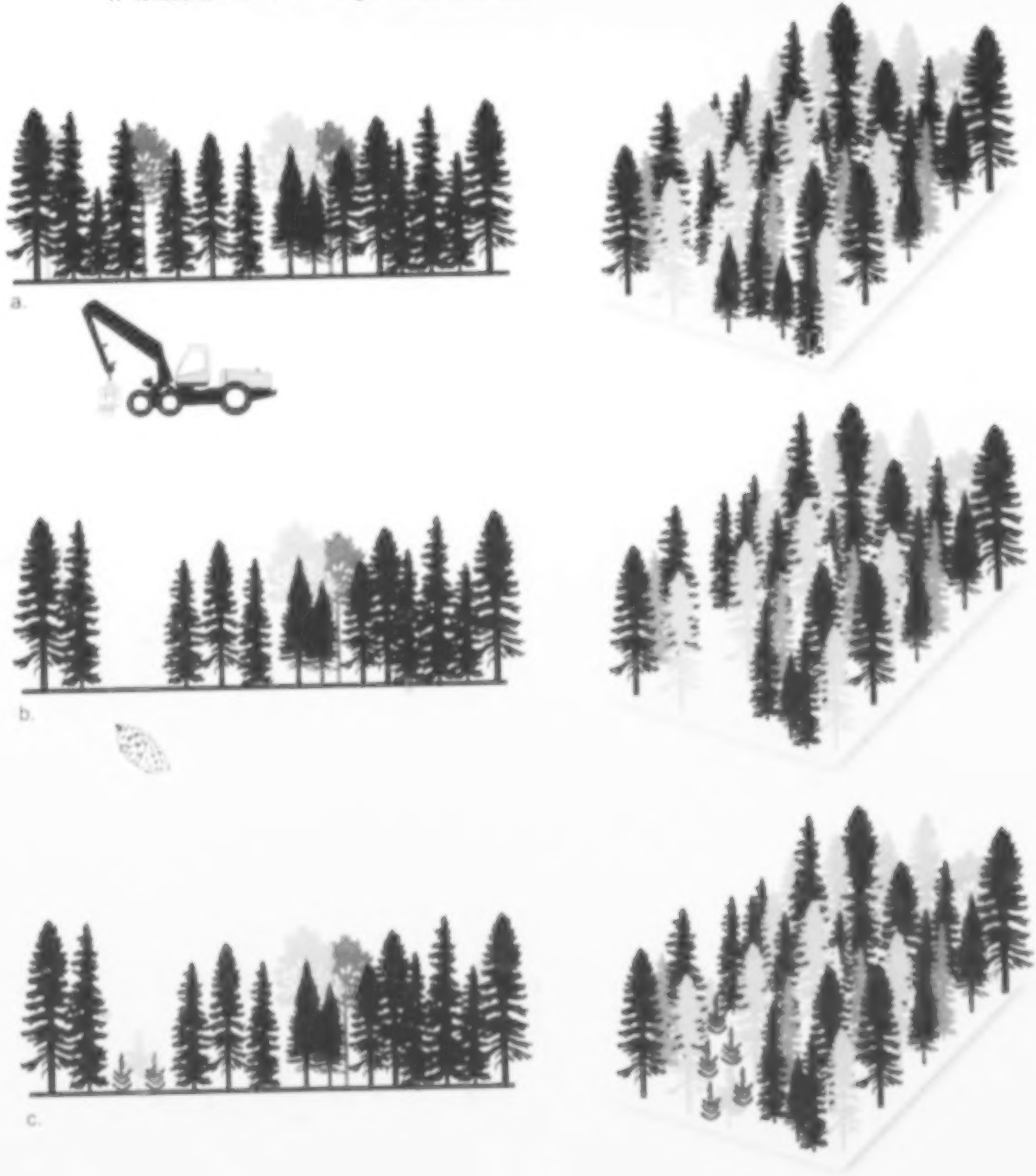
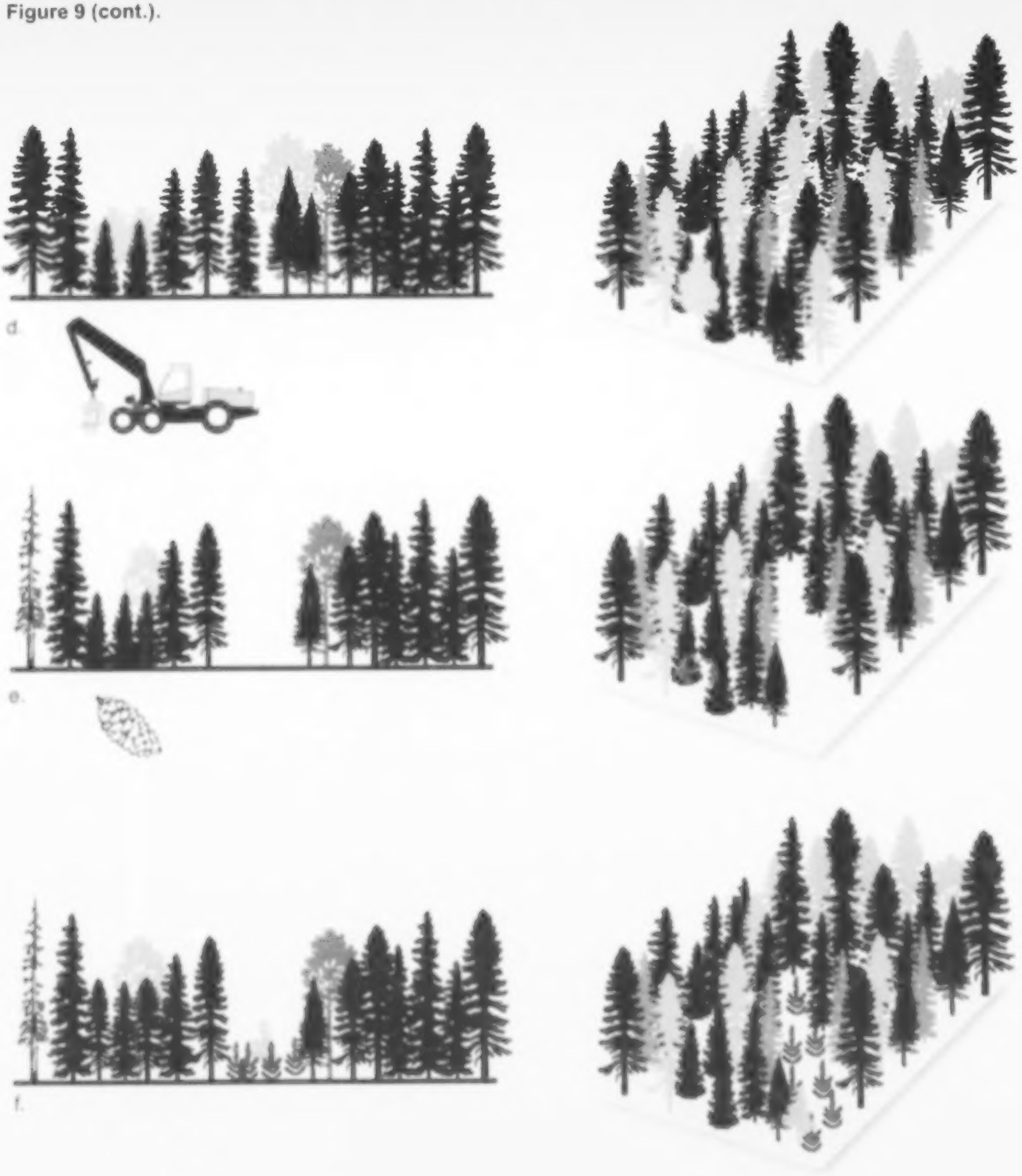


Figure 9 (cont.).



intolerant species, such as white birch, may be promoted.

Overstorey Retention

For the clearcut and shelterwood silvicultural systems, a certain portion of the original overstorey must be retained after final harvest to satisfy the requirements of the NDPE guideline (OMNR 2001b). Enhanced retention levels above the NDPE guideline requirements can be used to meet other objectives (e.g. wildlife and biodiversity) (Franklin *et al.* 1997, Mitchell and Beese 2002).

Enhanced overstorey retention can be implemented where a portion of the canopy that would normally be removed is retained to enhance structural diversity. Snags are eventually created when these retained stems die, increasing the structural complexity of the stand. When overstorey retention is applied with the shelterwood system, the resulting stand development patterns will differ due to the continuous modification of the understorey microclimate that overstorey retention produces (there is no final cut to provide full sunlight). Understorey tree growth will be reduced. Such a change in the stand development pattern is not as likely to occur if overstorey retention is used in conjunction with the selection system, where continuous modification of the understorey microclimate already occurs.

Partial Canopy Removal Methods

Silvicultural systems and treatments that result in partial canopy removal (e.g. selection systems, shelterwood systems, compositional treatments, or pre-commercial thinning) must ensure that "high-grading" does not occur. High-grading is the removal of the most commercially valuable trees (high-grade trees), often leaving a residual stand composed of trees of poor condition or undesirable species composition. High-grading may have both genetic and long-term economic or stand health implications (Helms 1998).

In partial canopy removal methods where only the species or individual trees of the highest timber value are removed, the result is a stand of unmerchantable overstorey trees. If these remaining trees have the potential to interfere with the successful establishment and subsequent development of the new stand, then these stems must be treated (e.g. felled, girdled, or treated with herbicide). Otherwise, this stand will be considered to have been high-graded.

LOGGING METHODS

Logging method describes those components of a tree which will be removed post-harvest from the cut block to the roadside for further processing or transportation and indicates the extent and location of initial processing. Types of logging methods include full-tree, tree-length, and shortwood.

The *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996) uses logging method as a reference point for documenting special restrictions (e.g. type of logging equipment or season of harvest) to ensure site compatibility.

Full-tree Logging

Full-tree logging is the removal of the entire crown and bole to the roadside where limbing and topping occurs. Full-tree logging will influence the number and distribution of cones left on a site and the amount of slash accumulation (Bowling and Goble 1994). While this may reduce the potential for natural seeding, the reduction of slash on a site can make it easier to plant trees or promote aspen root suckering.

Full-tree logging is not compatible with partial canopy removal methods. The equipment used requires wide corridors for operation and there may be a high level of damage (10 to 20 percent) to the remaining stems (Pulkki 1996) or advance growth.

Tree-length Logging

Tree-length logging is the removal of only the merchantable length of the tree to the roadside. Limbing and topping occur at the stump. Tree-length logging may create a similar level of damage to residual stems as that caused by full-tree logging

(Pulkki 1996). The feller-buncher/in-stand stroke delimbing system is not advised in partial canopy removal situations due to the potential damage to residual trees by the stroke delimber.

Shortwood Logging (cut-to-length)

Shortwood logging is the limbing, topping, and cutting-to-length of trees at the stump, followed by removal of the logs to roadside (Richardson and Makkonen 1994). The cut-to-length mechanical processing system provides low-impact machine harvesting and is suitable for conventional clearcutting as well as partial canopy removal methods.

This logging method allows for:

- reduction of damage to residual stems
- protection of advance growth
- site protection by distributing unmerchantable stems and branches on the ground for machine travel (David *et al.* 2001)

RENEWAL TREATMENTS

Forest renewal normally includes site preparation and regeneration treatments, which are used to establish a new cohort of trees (OMNR 1996).

Site Preparation

Site preparation is the disturbance of the forest floor, upper soil horizons, and/or vegetation prior to regeneration. The primary objective of site preparation is to create enough suitable, well-spaced microsites for the establishment of desirable species through natural or artificial means (Kennedy 1988, Örlander *et al.* 1990, Sutherland and Foreman 1995). Other objectives may include:

- reducing, redistributing, or aligning slash on the site
- providing access for regeneration activities
- reducing fire hazard
- manipulating wildlife habitat

Site preparation can be conducted using manual or motor-manual techniques, mechanical equipment, chemical (herbicide) application, prescribed burning, or a combination of these approaches (OMNR 1996). Depending on the site, species, and method of site preparation used, the creation of suitable microsites may (Kennedy 1988, Örlander *et al.* 1990, Sutherland and Foreman 1995):

- reduce or suppress competing vegetation
- reduce frost risk
- improve soil moisture, aeration, and drainage
- increase soil temperature
- increase availability of soil nutrients

Note: Although scarification is usually considered a site preparation method (as it is in this guide), the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996) classifies it as a regeneration method.

Selecting a Site Preparation Method

Site preparation can be an essential element in the regeneration of conifer species on fertile boreal mixedwood sites. To achieve management objectives and to minimize the potential for site damage, site preparation treatments must be matched to the site, employed at the appropriate intensity, and applied at the right time. Site preparation should:

- consider the impact on potential competing species
- mimic a natural disturbance that gives the desired species an advantage over a competitor (Oliver and Larson 1990)
- be completed pre- or post-harvest in a timely fashion to avoid development of competition and/or to take advantage of seed dispersal opportunities from standing seed trees (Jeglum 1984, Walker and Sims 1984, Sutherland and Foreman 1995, Fleming and Mossa 1996)
- be integrated with the silvics of the desired species; for example, a light vegetative cover may provide frost protection to susceptible seedlings while interfering little with growth (Sutton 1984, Lundmark and Halgren 1987)

- avoid potential negative impacts:
  - drying out and frost heaving on fine-textured soils and nutrient loss if too much of the organic layer is removed (Weetman and Vyse 1990)
  - soil compaction on wet soils and soils with high clay content; soils can recover from compaction within two years for coarse soils while clay loam tills can take over 20 years (Corns 1988)
  - erosion, especially on steep slopes (Walstad and Kuch 1987)
  - promotion of resprouting in woody shrubs and undesired hardwood trees (MacKinnon and McMinn 1988)
  - promotion of competing species that are established from wind-borne seed, due to the creation of exposed mineral soil seedbeds
  - promotion of decay in some species, such as aspen, through root and stem damage (Basham 1982b)
  - damage or loss of advance growth

Operational considerations include:

- number and distribution of residual trees
- number and distribution of stumps
- cover and depth of residual slash
- depth of forest floor
- soil depth, coarse fragment content, and bedrock exposure
- number and distribution of wet pockets within otherwise suitable areas
- access (e.g. road conditions and slope)

Site Preparation Methods

Site preparation methods include manual, mechanical, and chemical methods, and prescribed burning. More than one method may be combined.

Manual Site Preparation

Manual site preparation may involve the use of boot screefing or manual or motor-manual tools (Harvey *et al.* 1998) to remove, set aside, or suppress undesirable vegetation and to otherwise prepare microsites for regeneration.

Boot screefing is a common manual site preparation technique used after partial canopy removal and clearcutting. It is most often used where the forest humus layer is less than five to ten centimetres in total thickness. Boot screefing prevents damage to any advance growth and desirable residual trees and minimizes disturbance of the seed bank and the organic-mineral soil interface.

Manual trampling or binding of stems is an option to control woody shrubs where mineral soil exposure or soil mixing is not required. For example, trampling of mountain maple stems in partially cut boreal mixedwood stands appears to be an effective technique since trampling does not promote re-sprouting (Aubin and Messier 1999, Kneeshaw *et al.* 1999). This may be a useful technique to control woody vegetation prior to underplanting.

Manual or motor-manual site preparation may be useful when biological or physical constraints make mechanical site preparation methods inappropriate. For example, manual site preparation can be useful in partial canopy removal scenarios where it may be difficult to manoeuvre mechanical site preparation equipment.

Manual site preparation tools include mattocks, grub hoes, axes, brush hooks, shears, and machetes. Motor-manual site preparation tools include brushsaws and chainsaws for removing woody shrubs (Harvey *et al.* 1998) as well as motor-manual scarifiers mounted on brushsaws. These motor-manual scarifiers can provide innovative treatments such as spot scarification beneath a partial canopy. An evaluation of several motor-manual scarification devices is provided by Cormier (1989) and Maxwell (1989). Site conditions, including type and abundance of ground vegetation determine the efficacy of brushsaw-mounted scarifiers and dictate the choice of the most appropriate scarifier attachment.

Mechanical and Chemi-Mechanical Site Preparation

Mechanical site preparation involves the use of machinery with self-propelled prime movers to prepare microsites for regeneration (Smith 1986, Sutherland and Foreman 1995). It results in a relatively larger percentage of mineral soil exposure or mineral soil mixing compared to manual or motor-manual techniques.

Mechanical site preparation often affects soil moisture availability and soil temperature. The removal or mixing of organic material with the mineral soil can increase soil moisture availability, resulting in better seed germination, seedling establishment, and growth. It can also increase soil temperature and extend the frost-free period. Increased soil temperatures promote seedling root growth. Warming of the forest floor also has positive effects on nutrient availability by promoting organic nitrogen mineralization in the humus layer and slash decomposition and by enhancing the growth of beneficial fungi.

Mechanical site preparation generally contributes to only short-term control of competing vegetation (MacKinnon and McMinn 1988, Bedford and MacKinnon 1996). Mechanical site preparation may be combined with a herbicide application in a single operation, which is referred to as chemi-mechanical site preparation (see chemical site preparation). Mechanical site preparation implements vary in their impact on the control of competing vegetation (White, in prep.). Sutherland and Foreman (1995) provide case study summaries of the response of competing vegetation to mechanical site preparation for various stand and site conditions in northwestern Ontario.

Mechanical site preparation is not required or is not suitable in the following situations (Walstad and Kuch 1987, Von der Gonna 1992):

- sites that have adequate natural seedbeds
- sites that have an adequate amount of desired advance growth
- wet pockets within otherwise suitable areas
- sites with high amounts of surface stones and boulders
- steep slopes

There are five general categories of mechanical site preparation applicable for use on boreal mixedwood sites used primarily to promote conifers. These methods vary in the amount of disturbance of the forest floor and in the degree of mixing of the organic layers with the underlying mineral soil. The five categories are screefing (upland), inverting, mounding, trenching, and mixing.

Screefing

Screefing (including scalping, raking, and shearblading) is the removal or displacement of the organic layer to expose or scarify (lightly disturb) the underlying mineral soil[1] (Ryans and Sutherland 2001). Screefing can be done in spots, in a series of patches, or as a broadcast treatment. Ryans and Sutherland (2001) describe the variety of equipment that can be used for screefing in both conventional clearcut and partial canopy removal situations.

Blade or scalp site preparation treatments, either before harvest or following partial canopy removal, require equipment that can manoeuvre efficiently in intact stands or around residual trees following partial canopy removal.

Although shearblading is most commonly used on lowland *Sphagnum* sites, it may also be used on boreal mixedwood sites to remove small residual trees, brush, and stumps. However, this treatment is restricted to stone-free soils.

Inverting

Inverting involves "flipping over" parts of the forest floor organic layer, with or without the underlying mineral soil, onto the adjacent undisturbed forest floor. The inverted layer may be broken, but no mixing takes place between the inverted mineral soil layer and the undisturbed duff. Inverting can be done either as regularly spaced spots or as continuous strips (Sutherland and Foreman 1995).

The limitations of inverting include:

- ineffectiveness on sites with abundant competition
- drying out and frost heaving on fine mineral soils such as clays (McMinn and Hedin 1990)

Mounding

Mounding is a form of spot site preparation where raised planting spots are created. Forest floor material is inverted onto the adjacent, undisturbed forest floor and capped with mineral soil. Mounding can reduce competition and can create elevated microsites that provide tree seedlings with higher soil temperatures, better aeration, and well-drained conditions (Nilsson and Örlander 1995, Örlander *et al.* 1996). Planting white spruce on mechanically prepared mounds has proven to be a successful treatment in northern British Columbia. Seedlings planted on mounds demonstrate the same long-term mechanical stability as seedlings planted without site preparation (Heineman *et al.* 1999).

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[1] see note on scarification, page 22

Trenching

Trenching involves removing, then mixing, both the mineral soil and organic layers into berms on top of the adjacent, undisturbed forest floor (Sutherland and Foreman 1995). Trenching is generally done using disc trenchers, cone scarifiers, or heavy barrel drags.

Mixing

Mixing is the incorporation of the organic layer and fine debris into the underlying mineral soil using rotavators or other devices (NRC 1995, Sutherland and Foreman 1995). This technique is not suitable for stony or rough ground. Mixing avoids the problems of waterlogging or restricted root growth from compaction. It can facilitate the re-establishment of soil organisms following clearcutting, thus enhancing seedling growth, and can help control competition (McMinn and Hedin 1990). Soil mixing has the potential to increase organic matter decomposition as a result of better soil aeration and drainage (Mallik and Hu 1997).

There are several concerns with mixing. It can encourage resprouting of competing woody vegetation (Sutherland and Foreman 1995) and may cause leaching of nutrients immediately following site preparation. These potential negative effects can be limited by mixing only individual planting spots (McMinn and Hedin 1990).

Chemical Site Preparation

Chemical site preparation involves applying herbicide to a site prior to regeneration. This treatment can be used alone or in combination with other types of site preparation. Chemical site preparation can be used before a prescribed burn (brown and burn) to enhance the effectiveness of the burn (Buse and Bell 1992). It can also be used before, during, or after mechanical site preparation to reduce competing vegetation. When herbicides are applied in one operation with mechanical site preparation, the treatment is referred to as chemi-mechanical site preparation.

The herbicides commonly used in the boreal mixedwood forest of Ontario are glyphosate, hexazinone, triclopyr, and simazine. Susceptibility of boreal mixedwood species to these herbicides is reviewed by McLaughlan *et al.* (1996). Suggested application times for glyphosate and hexazinone are outlined by Carruthers and Towill (1988). Before undertaking a chemical site preparation program, a wide range of technical, social, political, and legal issues must be addressed (Boyd 1982, Walstad and Kuch 1987, OMNR 1991a, Brand 1992).

Chemical site preparation:

- tends to be more effective in reducing competition than other site preparation methods (Bell *et al.* 1992)
- may be more effective in reducing competition than chemical cleaning one year after planting (Wood and von Althen 1993)
- can be used at different times of the year with a variety of techniques on almost any type of terrain and any size of area
- does not disturb the surface soil; therefore, wind-borne seeds and those in the soil seed bank have less opportunity to germinate
- minimizes soil disturbance (and potential nutrient loss) (Walstad and Kuch 1987)
- can be used in areas with advance regeneration (after hardening off)
- indirectly controls tree-damaging rodents (Boyd 1982) by altering habitat

Other considerations for the use of chemical site preparation include:

- potential for limited effectiveness if the targeted competing species is not susceptible to the chemical (McMinn and Hedin 1990)

- seasonal restrictions, as some herbicides must be applied when competitors are in leaf (Walstad and Kuch 1987) and conifers are hardened off (e.g. if relying on advance growth)
- restrictions on ground application techniques when competing vegetation is taller than two metres (Bell *et al.* 1992)
- some seed-bank species (e.g. pin cherry [*Prunus pensylvanica*]) can be stimulated by herbicide application (Mallik *et al.* 1996)
- some vegetation can resprout if the chemical is not translocated to the rootstock/rhizome (Bell *et al.* 1992)

Broadcast Spraying

Broadcast spraying involves treating an entire stand using aerial or ground-based equipment and is effective for removing competing vegetation such as hardwoods and shrubs. This approach requires consideration of factors such as off-target deposition, weather, and seasonal restrictions (Mallik *et al.* 1997). Ground broadcast spraying is an effective chemical site preparation approach that allows the control of stems or species in both conventional and partial canopy removal scenarios (Bell *et al.* 1996).

Ground broadcast sprayers include boom, cluster-nozzle, high-pressure gun, air-blast, wick, and granular applicators (Desrochers and Dunnigan 1991). A cluster-nozzle sprayer may be used to apply liquid herbicide in a wide swath. It has the advantage of producing relatively uniform droplets, making the herbicide less subject to drift which may occur with other sprayers. The air-blast sprayer has several spray nozzles in front of a power-driven axial or radial fan which delivers a forced-air column of fine droplets. The air-blast sprayer has the ability to bend its spray pattern around obstructions such as residual trees. This ability makes air-blast sprayers especially appropriate for chemical site preparation in understorey and partial canopy removal situations.

Band Selective Spraying

Band selective spraying involves the aerial or ground application of herbicide in bands of predetermined widths. Banding to create alternating strips of treated and untreated ground permits the establishment of conifers while maintaining hardwoods. Banding (also called green striping) may be useful for maintaining aesthetic and wildlife habitat values during the regeneration phase.

Ground Selective Application

Ground selective application involves the application of herbicides to target individual stems or species and/or small areas to be regenerated. A variety of hand-held equipment is available to selectively remove unwanted vegetation before planting or seeding. These include backpack sprayers, brushsaws with attached herbicide applicators, spotguns, stem injectors, and wick (wiper) and granular applicators (Otchere-Boateng and Ackerman 1990, Mallik *et al.* 1997, Campbell *et al.* 2001).

Backpack sprayers can be used for directed foliar application, where the herbicide is sprayed directly on the foliage to control woody and/or herbaceous vegetation. Backpack sprayers can also be used for basal bark treatment of small (less than 15 centimetres dbh) woody stems when the herbicide is in a form (ester or oil-soluble) that will penetrate the bark. Application of herbicides such as glyphosate onto the surface of freshly cut stumps is effective in reducing the vegetative reproduction of hardwood species. Cut-stump herbicide application can be carried out using a brushsaw with an attachment that applies herbicide to the bottom of the brushsaw blade as it cuts the stem.

Soil-active herbicides such as hexazinone can be applied with a spotgun to remove competing vegetation from individual planting sites. This approach is useful for reducing aspen and grass in boreal mixedwood stands (Bell *et al.* 1996). Herbicide application directly into undesirable woody stems can be done using the "hack-and-squirt" method, where several cuts are made in the bark with an axe and herbicide (usually glyphosate) is subsequently squirted into the stem. Injection of the herbicide directly into stems can be carried out with lance-type injectors.

Wick and granular applicators have limited usefulness in boreal mixedwood stands (Michael Irvine, pers. comm.). Since preservation of a portion of the hardwood component is often a goal in boreal mixedwood management, granular applicators would have to be fairly small, leading to calibration problems. Since the only granular product registered for forestry use is hexazinone, a liquid application of hexazinone applied with a backpack sprayer or spot-gun may be more effective. Wick applicators have not generally been used in forest management.

Prescribed Burning

Prescribed burning is the knowledgeable application of fire to a specific land area to accomplish predetermined land management objectives (Merrill and Alexander 1987, OMNR 2002). Prescribed burning emulates wildfire, the most important stand-replacing disturbance agent in the Canadian boreal forest (Weber and Flanigan 1997). The *Prescribed Burn Planning Manual* (OMNR 1997a) provides the policy, procedures, and planning framework for the application of prescribed fire in Ontario. Prescribed burning can (Johnston 1971, Chrosciewicz 1976, McRae 1986, 1995, Aksamit and Irving 1984, Sutton 1985, Archibald and Baker 1989, Bell *et al.* 1992, Luke *et al.* 1993, Archibald *et al.* 1994, Wiltshire and Archibald 1998, McRae *et al.* 2001b):

- produce a suitable seedbed for natural or artificial seeding
- remove slash to improve access, increase planting spots, and reduce fire hazard
- improve the soil nutrient regime
- raise soil temperatures by removing insulating surface organic layers, which may extend the period of favourable growing conditions
- reduce insect (pest) populations
- remove or control competing species and promote the growth of desired species (e.g. remove undesirable balsam fir)

The effect of prescribed burning on competing vegetation is mostly of a temporary nature, but stand dynamics can be affected over the long term (Methven and Murray 1974, Jeglum and Kennington 1993).

Depending on management objectives, prescribed fire can be applied either pre- or post-harvest. The purpose of pre-harvest burning is to prepare a receptive seedbed and control competing vegetation in an attempt to establish regeneration before harvest occurs. Post-harvest fire is used on sites where regeneration is usually assisted by seeding or planting and where live, residual, overstorey trees are not required (OMNR 1998a).

Pre-harvest understorey prescribed burning is not suggested for promoting any of the defining boreal mixedwood species since their thin bark and shallow root systems make these species susceptible to damage from even low-intensity fires (Haeussler 1991, Wedeles *et al.* 1995). In addition, low-intensity understorey burning is not likely to be effective in promoting regeneration of species such as white spruce from natural seeding (Purdy *et al.* 2002).

Post-harvest prescribed burning usually involves broadcast burning of woody and herbaceous material over an open area. It can be as effective as mechanical site preparation in creating favourable microsites for regeneration and growth of spruce in northern Ontario (McRae 1985b, Arnup 1989, Wiltshire and Archibald 1998).

Regeneration

Regeneration is the establishment of a new cohort of trees either by natural (self-sown seed or by vegetative means) or artificial means (direct seeding or planting).

Selecting a Regeneration Method

There are many factors that influence the selection of a regeneration method, including:

- quantity and distribution of advance growth
- availability of seed on a site
- reproductive habits of the desired and competitive species
- availability of suitable microsites
- availability of suitable nursery stock and/or seed
- access to site
- slash volume and distribution
- site and stand characteristics, limitations, and hazard potentials associated with ecosites
- management objectives and constraints

Site and stand constraints often limit the use of natural regeneration. Combinations of natural and artificial regeneration, known as blended regeneration, may be used under some conditions.

Natural Regeneration

Natural regeneration is the establishment of desired tree species by natural seeding, sprouting, suckering, or layering (NRC 1995, OMNR 1996). The success of natural regeneration depends upon the autecology of a species (e.g. seeding habits, potential for vegetative reproduction, requirements for seed germination and early seedling establishment, and tolerance of shade) and the condition of the seedbed (Groot *et al.* 2001).

Natural regeneration presents opportunities to maintain local gene pools. Higher initial establishment densities may result in better stem form and wood quality than that of planted stands (Janas and Brand 1988). However, naturally regenerated stands have more variable stocking, clumping, and species composition than do planted stands. In addition, natural regeneration often requires an extended regeneration period, contributing to an increase in the rotation age of the next stand. Groot *et al.* (2001) provides an excellent review on the use of planned natural regeneration for conifers in Ontario.

Advance Growth

Advance growth refers to young trees under existing stands capable of becoming the next crop (NRC 1995). Advance growth is usually composed of species that are mid-tolerant to tolerant of shade and are often a different species than that dominating the overstorey (Weetman and Vyse 1990). Balsam fir and black and white spruce may occur as advance growth in boreal mixedwood stands.

Protection of advance growth is an operational practice used in conjunction with any of the three silvicultural systems. The objective is to protect desirable, non-merchantable stems (usually less than 10 centimetres dbh) during the removal of the main canopy. Protection of advance growth involves restricting equipment to established and marked trails and spacing skid trails as far apart as possible. Harvesting in winter or with high floatation equipment in summer is preferable to minimize damage to advance growth (Groot 1987, Archibald and Arnup 1993). In boreal mixedwood silviculture, advance growth may be used to supplement other regeneration treatments such as planting or seeding.

Natural Seeding

Natural seeding is the dispersal by natural means of seeds from standing trees or from cone-bearing slash. Seeds may be dispersed by wind, birds, mammals, gravity, flowing water, or be released by fire from serotinous or semi-serotinous cones (NRC 1995).

Natural regeneration from seed requires the successful completion of a chain of events involving flowering, cone development, seed dispersal, germination, establishment, and early seedling growth. If this chain is broken (e.g. a drought limits seedling establishment), it can result in regeneration failure and a delay in renewing the stand. Success can be achieved when a good seed year is combined with a suitable seedbed and adequate moisture during the growing season.

Seed years in Ontario generally occur every four years for black and white spruce. Spruce seed years cannot be predicted more than one growing season in advance, although they tend to occur in the summer following a year when bud differentiation occurred during a period of hot, dry weather (MacLean 1959, Hughes 1967, Nienstadt and Zasada 1990, Greene *et al.* 2000). A seed year can be assessed in late June of the same year of planned harvest using binoculars to count the enlarging seed cones. It can also be evaluated during the year preceding harvest, by examining buds from the upper crowns of trees harvested in nearby areas, or by forcing buds on harvested branches after a post-chilling submersion in water.

Natural seeding is not a recommended technique for regenerating aspen stands. Most aspen seed is viable for only two to three weeks after dispersal (Navratil 1991) and seedbed conditions must be receptive during this period (Steneker 1976).

Vegetative Reproduction of Intolerant Hardwoods

Vegetative reproduction of intolerant hardwoods includes root suckers and stump sprouts. Root suckers are shoots that originate from adventitious buds on roots. Sprouts refer to shoots that arise from a cut stump. The term coppice is used to refer to both stump sprouts and root suckers.

For futher information about vegetative reproduction see Sections IV, VI, and VII.

Artificial Regeneration

Artificial regeneration is the establishment of desired tree species by either direct seeding or planting seedlings or cuttings (NRC 1995, OMNR 1996).

Direct Seeding

Direct seeding is the manual or mechanical sowing of seeds (NRC 1995). The biological requirements for direct seeding are more rigorous than for planting because both successful seed germination and seedling establishment are required. Successful direct seeding depends on proper site selection, adequate site preparation, and good seed distribution. Factors affecting success include harvest method, site selection, site preparation, timing, seeding rate, and quality of seed (Adams *et al.* 2001).

The time between harvesting, site preparation, and seeding should be minimal to avoid competition problems. Ideally, seeding of conifers should be done on snow in late winter, or in the spring shortly before snowmelt, so that soil moisture is optimal. Fall seeding is also an option, although there is increased risk of premature germination and seed loss due to predation, burial, or other causes.

The best results with conifer seeding are obtained on a combination of site types and seedbeds that provide plentiful but not excessive soil moisture and warm soil temperatures (Fleming *et al.* 2001). Seeding is most successful on sites where competition from other vegetation is minimal. Site preparation and vegetation management will likely be required on any boreal mixedwood site where direct seeding is the primary means of regeneration. Direct seeding is not advised on sites where Canada blue-joint is expected to compete with the germinants. This grass is a serious competitor of both white (Lieffers *et al.* 1993) and black (Bell *et al.* 2000) spruce.

Some of the advantages of seeding compared to planting include:

- well-proportioned seedlings with naturally-developed root systems are established (Cayford 1974, Fleming *et al.* 2001)
- the composition, densities, and distribution of species in direct-seeded stands may closely approximate those of natural stands (Fleming *et al.* 2001)
- less planning time is required (e.g. seedlings may need to be ordered up to 18 months in advance of planting)

Some of the limitations of seeding include:

- seed losses to small mammals and birds
- difficulty in achieving uniform seed distribution (Foreman and Riley 1979, Bell *et al.* 1992, Adams *et al.* 2001).
- high dependence on site conditions, leading to inconsistent results, especially with black spruce on upland sites (Richardson 1974)
- potential inefficient use of improved seed (i.e. many seeds fall on poor microsites)
- loss of small germinants to competition or drought (Bell *et al.* 1992)

There may be operational impediments to the use of mechanized equipment for direct seeding where a full or partial canopy is to be retained.

Direct seeding includes broadcast seeding and precision seeding.

Broadcast Seeding

Broadcast seeding is the sowing of seeds more or less evenly over a whole area on which a forest stand is to be established (NRC 1995) and is typically applied following conventional clearcutting. It can be carried out with aerial or ground-based equipment (e.g. a hand seeder or a snowmobile-mounted seeder). Stocking levels are more directly related to the amount of receptive seedbed available than to the amount of seed applied (Riley 1980, Fleming and Mossa 1995).

Precision Seeding

Precision seeding is the systematic sowing of seeds by manual or mechanical means in an area on which a forest stand is to be grown (adapted NRC 1995). Precision seeding can be done either as spot seeding (sowing of seed within small prepared patches) with or without shelters, or as drill (row) seeding across an area (Haddon 1988, Davidson 1992, Sidders 1993, Adams *et al.* 2001). Precision seeding can be done either manually or with ground-based equipment.

Spot seeding using hand-held seeding devices provides the most reliable method of seed placement on receptive seedbeds. Stocking can be increased with seed shelters used in conjunction with hand precision seeding. The best results with seed shelters have been obtained on well drained upland sites with little competition.

Planting

Compared to other regeneration methods, planting provides the greatest control over stand density and structure to achieve management objectives. Planting is suitable for a wide range of sites and is often the regeneration option chosen for productive and competitive sites.

Ecosite, site preparation method, stock type, and the type of planting tool used can influence the number and distribution of planting spots (McClain and Willcocks 1988).

Planting provides (Bell *et al.* 1992):

- a choice of stock types; an opportunity to match growing stock to the site
- a faster and often more successful method of re-establishing desired trees on a site
- planned control over species composition, spacing, and density (e.g. Smith 1986); uniformly spaced, planted stands may occupy the site more fully than stands established by seeding or other natural methods (Stiell 1982); high-density stands from seeding (either natural or artificial) can stagnate and only grow slowly in diameter (Janas and Brand 1988)
- an opportunity to change species composition (e.g. balsam fir to black spruce dominated stands)
- an opportunity to introduce genetically improved stock (faster growth rates, disease resistance)

The following are considerations when selecting planting as a regeneration option:

- the suitability of other less intensive regeneration options (Bryson and Van Damme 1994)
- the potential for ingress of naturals to cause overstocking (Willcocks and Bell 1995)
- availability of seed from the appropriate seed zone to grow the stock
- the requirement for site preparation prior to planting
- potential for damage or mortality to planted seedlings from herbivory (e.g. nursery seedlings can be more desirable to snowshoe hares than naturally-regenerated seedlings) (Rodgers *et al.* 1993)

Stock Types and Seedling Quality

Container Stock

Container stock refers to seedlings grown in a package that retains the growing medium and separates individual root systems during the growing phase (Odlum *et al.* 2001). The seedlings are planted with the roots still in the growing medium (NRC 1995).

Bareroot Stock

Bareroot stock refers to seedlings that will be planted with their roots bare of soil (NRC 1995).

In selecting a type of planting stock, a number of factors should be considered, including;

- availability of seed
- length of planting season (planting window)
- site characteristics such as soil depth, texture, and amount of slash
- handling requirements
- type of site preparation and subsequent tending treatments
- degree of competition on the site
- lead time required to obtain stock
- health and vigour of seedlings

- field performance of the stock type on boreal mixedwood sites and under varying levels of canopy removal

Seedling Quality

Seedling quality may be affected by nursery cultural practices and storage and handling techniques. Seedling quality can be determined by assessing morphological and physiological attributes as well as by visual inspection. Morphological attributes can be measured at the nursery prior to shipment or storage to determine if seedlings meet field specifications. These include measurement of height, diameter, and seedling balance (height:diameter ratio). Although seedlings may appear outwardly healthy, they may not perform well once outplanted if they have been stressed. Physiological attributes to determine performance after outplanting may be measured through standardized tests (Colombo *et al.* 1984, Colombo 1997). Seedlings should also be visually inspected regularly prior to planting and monitored for overheating, drying of roots, presence of pathogens, and physical damage (KBM Forestry Consulting *et al.* 2002).

Cluster Planting

Cluster planting involves planting groups of trees in patches within the regenerating stand. Hardwoods (typically aspen) may regenerate vegetatively in the areas between the groups, with a hardwood-free zone being maintained around the clusters to maximize spruce growth (BCMoF 2000). The objective of this arrangement is to promote a hardwood-conifer mixedwood where the hardwood and conifer components are managed in predetermined proportions. The number of clusters per hectare is controlled by varying the number of clusters and the inter-cluster distance (Figure 10). If conifer advance growth exists, it can also be protected to augment stocking. The hardwood component of the future stand will grow faster and, consequently, may be harvested earlier than the conifer component. A model based on light availability (LITE) has been developed in British Columbia to determine the optimum size of the hardwood-free zone to maximize spruce growth in aspen-white spruce mixtures (Comeau 2000).

Although it might also be possible to use black spruce for cluster planting, this approach has not yet been attempted with this species.

Timing of Regeneration Treatments

Many silvicultural treatments should be timed to coincide with certain periods or seasons throughout the year. In addition, the timing of silvicultural treatments in relation to final harvest should be considered since many treatments may be conducted either pre-harvest, post-harvest, or, to a lesser extent, during harvest. For example, tending may be implemented to treat advance growth prior to harvest, to remove undesirable stems during harvest, or to release regeneration that has established after harvest.

With respect to pre-harvest treatments, understorey scarification in a seed year and underplanting have particular application in boreal mixedwood management.

Understorey Scarification in a Seed Year

Timing pre-harvest understorey scarification with a seed year and delaying clearcut harvest until after seed release increases the chance of securing successful natural regeneration of spruce, particularly white spruce. Root raking has been suggested as a method of understorey scarification to promote natural spruce regeneration on boreal mixedwood sites prior to harvesting in a seed year (Greene *et al.* 2000).

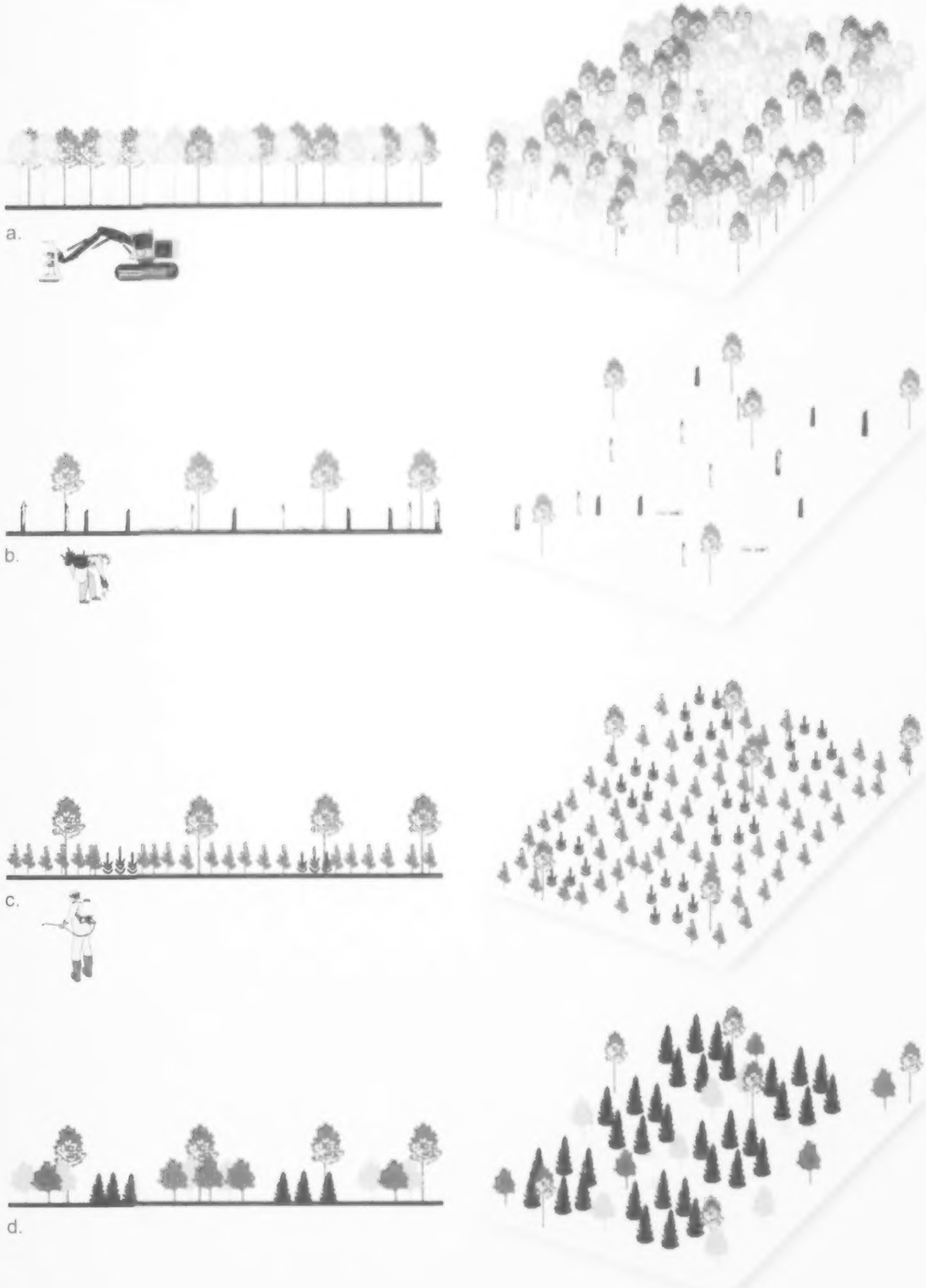
Pre-harvest understorey scarification may also be implemented in a non-seed year. However, the harvest should be delayed for four years. Generally, a seed year will occur during this period and seedbeds will still be receptive (Greene *et al.* 2000). Harvest of the seed trees is then scheduled after seed release has occurred.

For further information relavent to this approach refer to Natural Seeding (page 28), Site Preparation Methods (page 22), and Section VI.

Underplanting

Pre-harvest underplanting creates a distinct two-tiered stand structure which is compatible with two-stage harvesting or shelterwood harvest.

Figure 10. An example of cluster planting using systematic location of white spruce cluster. The seedlings are planted in well-defined clusters spread throughout the new stand.



Advantages of underplanting include:

- moderated understorey microclimate favourable to white spruce establishment (Groot and Carlson 1996, Tanner *et al.* 1996, Groot *et al.* 1997, Man and Lieffers 1999, Delong *et al.* 2000)
- protection from some insects and disease (MacLean 1996, Su *et al.* 1996, Taylor *et al.* 1996, Man and Lieffers 1999)
- maximum potential yield and site occupancy (underplanting conifers in hardwoods) (Man and Lieffers 1999, Lieffers *et al.* 1999)

SUPPLEMENTAL REGENERATION

Supplemental regeneration refers to the application of one or more silvicultural treatments to establish trees in areas of inadequate stocking to meet compositional objectives.

REINITIATION

Reinitiation refers to the application of any combination of appropriate silvicultural treatments throughout a stand at the initiation stage when the composition or condition of the stand is deemed to be not acceptable.

GENETIC RESOURCE MANAGEMENT

Genetic resource management is "*the incorporation of genetic principles into forest practices in order to conserve genetic diversity in trees while promoting economic development through the maintenance and enhancement of productivity*" (Joyce *et al.* 2001). Silvicultural practices may have an effect on genetic diversity by changing the population structure (i.e. the distribution and abundance of trees) (Mullin and Bertrand 1999).

Boreal mixedwood management can involve both natural and artificial regeneration. The different impacts of natural and artificial regeneration on genetic variability must be considered. The genetic resource management principle for natural regeneration is the maintenance of a broad genetic base to reduce the risk of inbreeding and genetic drift that may otherwise occur in small, isolated populations. This goal can be achieved by ensuring that a large number of trees contribute to regeneration and that high-grading does not cause genetic degradation.

Genetic resource management principles for artificial regeneration involve seed source control of seed and planting stock and maintenance of a broad genetic base in tree breeding programs. Generic seed zones for all Ontario species have been derived using elevation and climate models to reduce the risk of using maladapted seed and stock in artificial regeneration programs (OMNR 1997b). Seed and planting stock must be used in the seed zone in which it originated, unless there is an indication that transfers are acceptable (OMNR 1997b) since seedlings may be poorly adapted to other climatic conditions when moved some distance from their geographic origin.

The five defining boreal mixedwood species can be classified as common species since they are well-represented throughout the landscape and gene flow among populations is usually relatively high. Because these species are common, they are not normally at any great risk for loss of genetic diversity across the majority of their range. However, genetic degradation can occur even within such common species if high-grading or overharvesting occurs at their range limit. These practices must be avoided to ensure the conservation of genetic diversity.

Associated boreal mixedwood species such as red and white pine and balsam poplar are classified as minor species (Dennis Joyce, pers. comm.). Minor species have low-density local populations and fragmented populations at the landscape scale. These minor species are the most vulnerable to genetic erosion and extirpation. Landscape-level silvicultural guidelines must be applied to ensure that these susceptible species do not gradually disappear.

Elements of management guidelines at various scales to conserve genetic diversity are covered in detail by Joyce *et al.* (2001). The major goal is to maintain genetically viable populations in which the genetic forces are in a dynamic balance.

Tree improvement programs are directed at improving the quality and growth of commercial forest tree species. Tree improvement strategies vary depending on differences in species biology, breeding objectives, and economic and political considerations. However, all tree breeding programs utilize the breeding cycle concept which consists of the following four elements: selection, breeding, testing, and operational seed production.

The primary conifer species of interest for artificial regeneration in boreal mixedwood management are white and black spruce. Genetics research has indicated that adaptive variation in traits such as height, diameter, wood quality, and phenology exist for both black spruce (Morgenstern 1978, Boyle 1985, Parker *et al.* 1994, 1996, Parker and van Niejenhuis 1996) and white spruce (Nienstaedt and Teich 1972, Teich and Holst 1974, Teich *et al.* 1975, Pollard and Ying 1979a, b, Radsliff *et al.* 1983, Murray and Skeates 1984, Khalil 1985, Corriveau *et al.* 1991, Peng *et al.* 1997).

In boreal mixedwood management, aspen and birch are often desired as component species at certain stages of stand development. Both of these species can be managed by natural vegetative reproduction, although birch also regenerates well from seed if suitable seedbeds are available.

For aspen, vegetative reproduction by root suckering causes aspen stands to develop as mosaics of clones. Genetic variation among aspen clones has been demonstrated for characteristics such as tree form, frost resistance, patterns of height growth, suckering and rooting ability, susceptibility to Hypoxylon canker (*Entoleuca mammata*), wood specific gravity, and fibre length (Davidson *et al.* 1988). This variation should be considered for any type of thinning since genetic differences have been shown to be responsible for much of the thinning response (Penner *et al.* 2001). Genetic improvement of aspen is currently a low priority in Ontario since excellent natural regeneration of aspen occurs by suckering and there has historically been no demand for planting stock.

No information is presently available on genetic variation of birch in Ontario and genetic improvement of birch is currently not a priority.

TENDING TREATMENTS

Tending is any operation that is carried out to improve the survival, growth, or quality of forest stands. Tending in boreal mixedwood management may involve cleaning, compositional treatment, juvenile spacing, liberation treatment, pre-commercial and commercial thinning, and pruning.

Selecting a Tending Treatment

The following factors should be considered when developing a prescription for a tending treatment (Jaciw 1969):

- management objectives
- accessibility and topography
- size and extent of competing vegetation
- desired species
- environmental considerations
- value of end product
- equipment and labour availability

Tending may have an impact on wood production (yield, quality, and value), species and genetic diversity (richness and evenness), soil conservation, and risk of loss to fire, insects, disease, and severe weather (Bell 2001).

Cleaning

Cleaning is a treatment conducted to release a regenerated stand from competing vegetation, including undesirable tree species. Cleaning allows crop trees to establish dominance of the site. Removal or suppression of competing non-crop vegetation speeds stand development toward a future forest of the desired composition, structure, and growth rate (Wagner *et al.* 2001).

Major competitors of spruce on boreal mixedwood sites include aspen, alder, mountain maple, beaked hazel, willow (*Salix* spp.), raspberry, sedges, and grasses (Buse and Baker 1991, Lautenschlager 1995). The type and timing of disturbance, pre-harvest stand condition, site characteristics, and autecology of competitor species all interact to influence post-harvest abundance of competing vegetation. For example, harvest methods on mixedwood sites that maintain a partial canopy can reduce the level of shade-intolerant competitors, such as Canada bluejoint, relative to total canopy removal (Landhäusser and Lieffers 1998).

Vegetation does not always have a level of impact on crop tree survival or growth that warrants an investment in cleaning (Oliver and Larson 1990). Some vegetative cover may be desirable to protect conifers, particularly white spruce, during establishment. Cleaning treatments must consider the tolerance of crop trees relative to the presence and abundance of vegetation, its impact on crop tree survival and growth, and the optimum timing for release.

Every tree species has a competition threshold. This threshold can be defined as the level of vegetation abundance where there is an abrupt increase or decrease in the rate of change in tree growth or survival (Wagner *et al.* 1989). In addition, there is a critical period during which cleaning must occur to prevent yield loss (Wagner 2000).

A variety of methods are available to remove or suppress non-crop vegetation (Wagner *et al.* 2001). Common methods include manual, motor-manual, and mechanical methods, and herbicide application. Others include animal grazing, mulching, cover crops, and biological control. Combinations of these methods may be prescribed to secure the desired future stand condition.

Manual and Motor-manual Cleaning

Manual cleaning involves manual cutting with motorized or non-motorized tools (e.g. motorized brushsaws, chainsaws, and axes), girdling, clearing or scalping with hoes, and hand pulling, trampling, or binding of unwanted vegetation. Manual and motor-manual cleaning are especially suited to harvest methods that leave an overstorey canopy, although these types of cleaning are costly, labour intensive, and can involve greater risks to operator safety than most other cleaning methods.

Clearing or scalping with hoes can be used to remove herbaceous or low-growing woody vegetation around crop trees, although it is generally only effective for one growing season (Wagner *et al.* 2001). Hand pulling of non-crop vegetation is of limited value in boreal mixedwood stands since the removal of the entire plant is usually only possible on coarse-textured soils. The vegetation must not have extensive or brittle root systems or the ability to resprout (Wagner *et al.* 2001).

Manual and motor-manual cutting are effective methods for controlling the density of conifer stems (e.g. unwanted balsam fir) and temporarily reducing woody tree and shrub vegetation. Substantial resprouting of woody vegetation generally diminishes treatment effectiveness on boreal mixedwood sites (Bell *et al.* 1997a, b, Reynolds *et al.* 1997). Consequently, multiple cleaning treatments over several years are usually required for successful control of unwanted hardwoods and woody shrubs. For greater control of resprouting, manual cutting can be combined with either herbicide application or a biological control agent (see Chemical Cleaning and Biological Control). Survival can be reduced in aspen by controlling cut height and season of cutting (Bell *et al.* 1999). Harvey *et al.* (1998) describes tools available for manual and motor-manual cutting.

Girdling involves removal of the bark and cambial layer (phloem) around the total circumference of larger stems (usually greater than 15 centimetres dbh) using motorized or non-motorized hand tools (Otchere-Boateng and Ackerman 1990). The wound must be wide enough to ensure that the cambium will not regrow and connect. Girdling is an effective technique to minimize resprouting when conducted in mid to late spring to coincide with reduced carbohydrate root reserves. Full control is not achieved until several years after treatment.

Mechanical Cleaning

Mechanical cleaning involves the use of self-propelled, wheeled, or tracked prime movers with motorized cutting attachments to remove woody vegetation. Various types of equipment may allow for either individual or broadcast removal of stems. Bell *et al.* (1996) suggests that non-selective cutting could be useful in boreal mixedwood management to remove all vegetation above the height of a uniformly-sized conifer crop. Mechanical cutting, like manual cutting, is most effective in mid-summer to reduce resprouting.

Chemical Cleaning

Chemical cleaning involves the use of herbicides to control non-crop vegetation. Herbicides are the most effective and least expensive means of providing longer term control of non-crop vegetation (Wagner *et al.* 2001).

The following factors should be considered in developing a chemical cleaning prescription:

- conifer seedlings can be damaged if sprayed before buds have hardened off and set (Walstad and Kuch 1987, Carruthers and Towill 1988, McLaughlan *et al.* 1996)
- the height and distribution of crop trees may limit use of some vehicle-mounted equipment because of potential physical damage to the seedlings
- combining chemical and manual treatments can be effective in cleaning operations to control coppice growth; for example, brushsaws with an attached herbicide applicator can be used to apply a systemic herbicide while cutting stems (Mallik *et al.* 1997)

Herbicides can be applied through aerial spraying or through on-ground treatments using vehicle-mounted equipment, backpack sprayers, or other hand application tools (refer to Site Preparation, pages 25 and 26, for description of appropriate herbicides and chemical application equipment).

Vegetation Management Alternatives

Animal Grazing

Research into the use of sheep grazing for forest vegetation control in Ontario began in the early 1990s (Foster 1998) and draft guidelines have been developed for this technique (Lautenschlager *et al.* 1993). Although sheep grazing appeared to be successful in releasing black and white spruce plantations in northeastern Ontario (Pickering and Richard 1993), it was subsequently determined that only a temporary reduction in non-crop vegetation abundance and a limited boost in tree growth occurred in the season following grazing (Luke and Vasiliauskas 1998). Wagner *et al.* (2001) suggests that although sheep grazing has not been tested on partially cut sites, it is not likely to be feasible in such conditions and is probably best suited to clearcuts. Bell *et al.* (1996) suggest that with effective flock management, sheep grazing can encourage spruce-aspen mixedwoods since herbs, grasses, and low shrubs can be removed and aspen and spruce taller than 1.5 metres will remain unharmed.

Mulching

Mulching is the placement of material on the ground around crop trees to smother and prevent the invasion of competing vegetation. Mulching is the only currently effective alternative method to herbicides to control herbaceous and low-growing woody vegetation (Wagner *et al.* 2001). Suggestions for the proper application of mulches are given by Strobl (1994). The high cost of mulches has limited their use to special, high-value plantations (Strobl 1993).

Cover Cropping

Cover cropping involves the regeneration of non-woody species that are beneficial or more competitive than existing competing vegetation but less competitive than the desired tree species. The intention is that the cover crop will outcompete the native competitors to either eliminate or at least suppress them but not outcompete the desired species. Experimental use of cover crops in northern Ontario has indicated that they are more difficult to establish in boreal than southern Ontario forests (Wagner *et al.* 2001). However, cover crops have shown potential for controlling competing vegetation in spruce plantations in northeastern British Columbia (Negrave and Kabzems 1996).

Biological Control

Biological control involves the introduction of naturally occurring fungi, bacteria, viruses, or herbivorous insects, or phytotoxins (naturally-occurring compounds produced by micro-organisms) to suppress or reduce plant populations (Wagner *et al.* 2001). Several native fungal pathogens and rhisosphere bacteria are showing potential as biological control agents of Canada blue-joint

(Winder and Macey 1998, Winder 1999, Macey and Winder 2001). The indigenous fungal pathogen *Chondrostereum purpureum* has been shown to reduce the vigorous regeneration of speckled alder (*Alnus incana* ssp. *rugosa*), red maple (*Acer rubrum*), aspen, and birch (Wall 1990, Dumas *et al.* 1997, Jobidon 1998, Harper *et al.* 1999, Pitt *et al.* 1999). Differences in susceptibility between aspen and birch could be useful in boreal mixedwood management when the objective is to promote an aspen dominated mixedwood. *Chondrostereum purpureum* is applied as a paste to cut stumps and is now registered for use in Ontario. However, the high cost of this product may limit its use to special high-value situations.

Compositional Treatment

Compositional treatment alters the proportion of species in the overstorey to meet compositional and/or structural objectives (Figures 11 and 12). Trees can be removed by cutting, girdling, or herbicide application. Stems that are removed may be merchantable or non-merchantable. One or more boreal mixedwood species may be targeted for removal in order to shift from one composition type to another. However, compositional treatments must ensure that site occupancy is recovered.

Juvenile Spacing

Juvenile spacing is the spacing of crop trees during the stand initiation stage. It is similar to pre-commercial thinning, except that it is carried out before canopy closure has occurred. At this stage of stand development, it may not be possible to select for dominance if it has not yet been expressed. Juvenile spacing does not alter the species composition of the stand.

Liberation Treatment

Liberation treatment is the release of young trees not past the sapling stage from the competition of distinctly older, overtopping trees (Smith *et al.* 1997). The overtopping trees can be removed by cutting, girdling, or herbicide application. Stems that are removed during this treatment may be merchantable or non-merchantable.

Thinning

Thinning is a form of partial canopy removal in an established stand that concentrates potential wood production of a stand on selected trees (Smith *et al.* 1997). Thinning does not include an objective to create space for regeneration and does not alter species composition.

Note: Attempts to combine regeneration and the benefits of thinning may compromise both objectives. If regeneration is the objective, the treatment should be regarded as shelterwood regeneration (rather than thinning), which places emphasis on the critical regeneration process of a silvicultural system (Smith *et al.* 1997).

Two types of thinning, pre-commercial and commercial thinning, are applicable to boreal mixedwood management.

Pre-commercial Thinning

Pre-commercial thinning is thinning that does not yield trees of commercial value and is also referred to as "thinning to waste" or "early stocking control" (Oliver and Larson 1990). The primary objective of pre-commercial thinning is to improve crop spacing, growth, and stem form, without altering the species composition of the future stand. In boreal mixedwood management, pre-commercial thinning can be applied at the stem exclusion stage of stand development for any of the following purposes:

- to increase individual tree volume and regulate stand density (Bell *et al.* 1990)
- to improve stand quality through the removal of diseased trees or those with poor form
- to modify wildlife habitat
- to improve future wood quality (Willcocks and Bell 1995)

Mechanical strip thinning and motor-manual thinning using brushsaws are the two most common pre-commercial thinning techniques used in Ontario. Stem injection and basal bark herbicide treatments can also be used to selectively thin hardwoods (Miller 1988, 1990). Removal of individual stems by motor-manual or chemical thinning targets the smallest,

Figure 11. Compositional treatment at stand initiation in an aspen leading mixture. At this stage of stand development, this example shows the aspen overstorey being controlled by manual spraying.

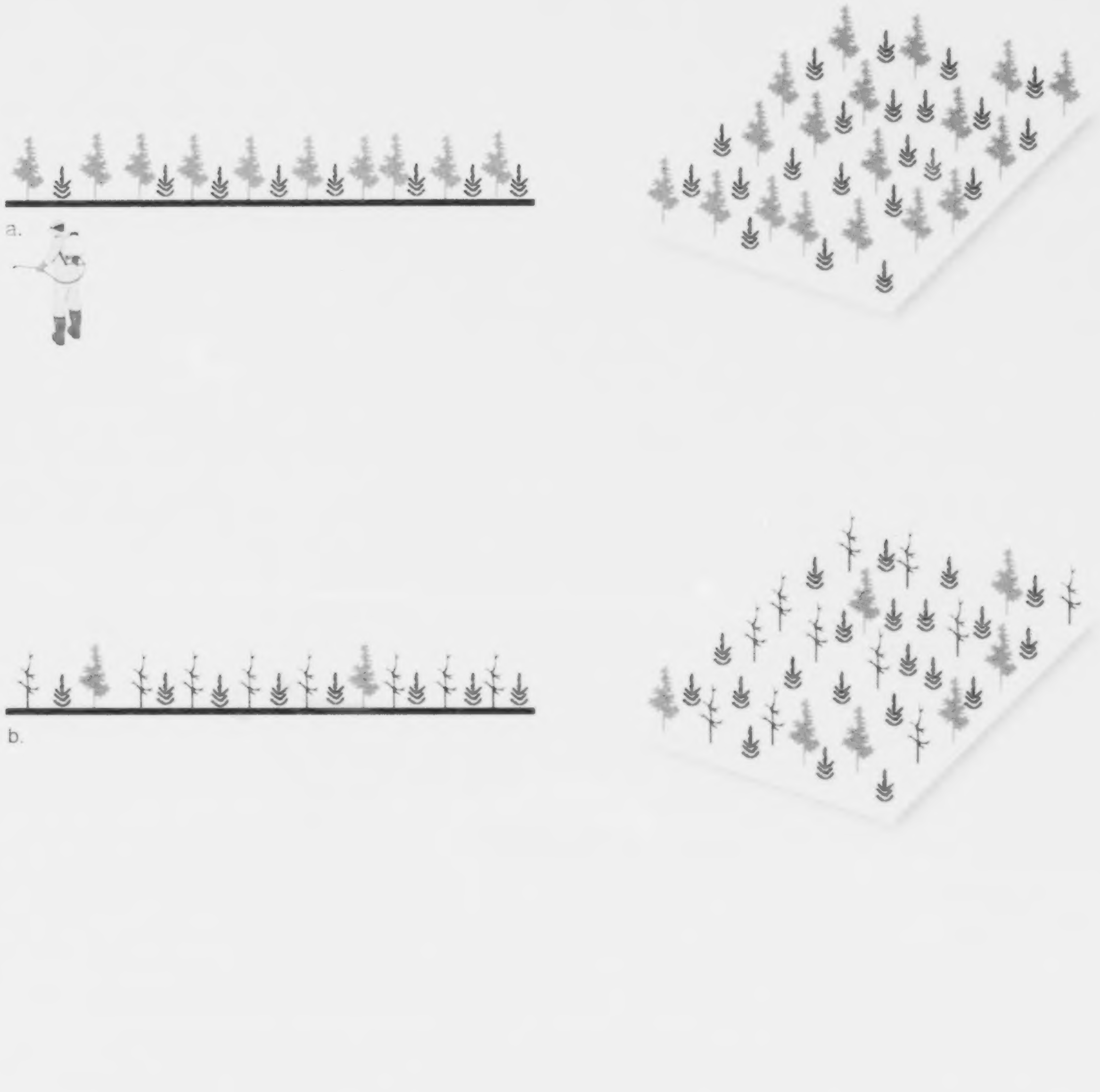
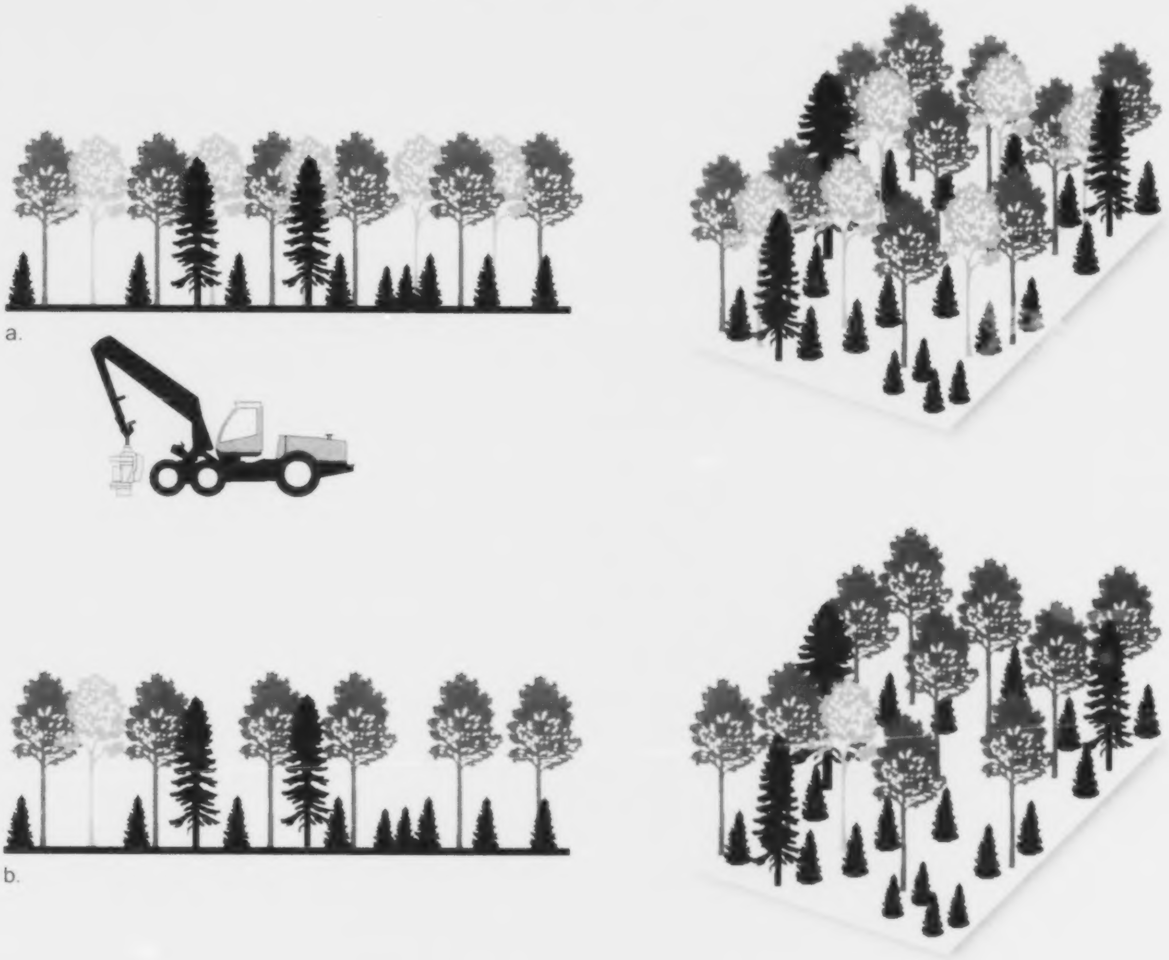


Figure 12. Compositional treatment at stem exclusion in an aspen leading mixture. At this stage of stand development, birch is controlled by harvest and removal from the stand.



most inferior trees in the stand. This is not possible with mechanical strip thinning as individual trees cannot be preferentially selected (David *et al.* 2001).

Commercial Thinning

Commercial thinning is the partial removal of overstorey trees in well stocked stands where some portion of the trees removed have reached a merchantable size and where the sale of the timber harvested will potentially earn a positive financial return (adapted from OMNR 1997c). The primary purpose of commercial thinning is to enhance the growth response (and perhaps form and quality) of the remaining overstorey stems. As opposed to compositional treatment, commercial thinning retains the original species composition of the overstorey. With commercial thinning, there is no regeneration objective.

Note: Although commercial thinning is usually considered a tending treatment (as it is in this guide), the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996) classifies it as a harvesting method because merchantable volume is being removed from the stand.

Considerations for commercial thinning include:

- species or species mixture
- stand age
- thinning intensity
- thinning type: specifying which crown classes (canopy position) will be treated (e.g. thinning from below)
- spatial distribution of the remaining overstorey stems
- genetic variation: e.g. genetic differences among aspen clones are responsible for much of the thinning response (Penner *et al.* 2001)
- windthrow risk: residual trees should have a slenderness coefficient ratio less than 100 (see Wind Damage, Section IV) and a live crown ratio of at least 30 percent to reduce windthrow risk

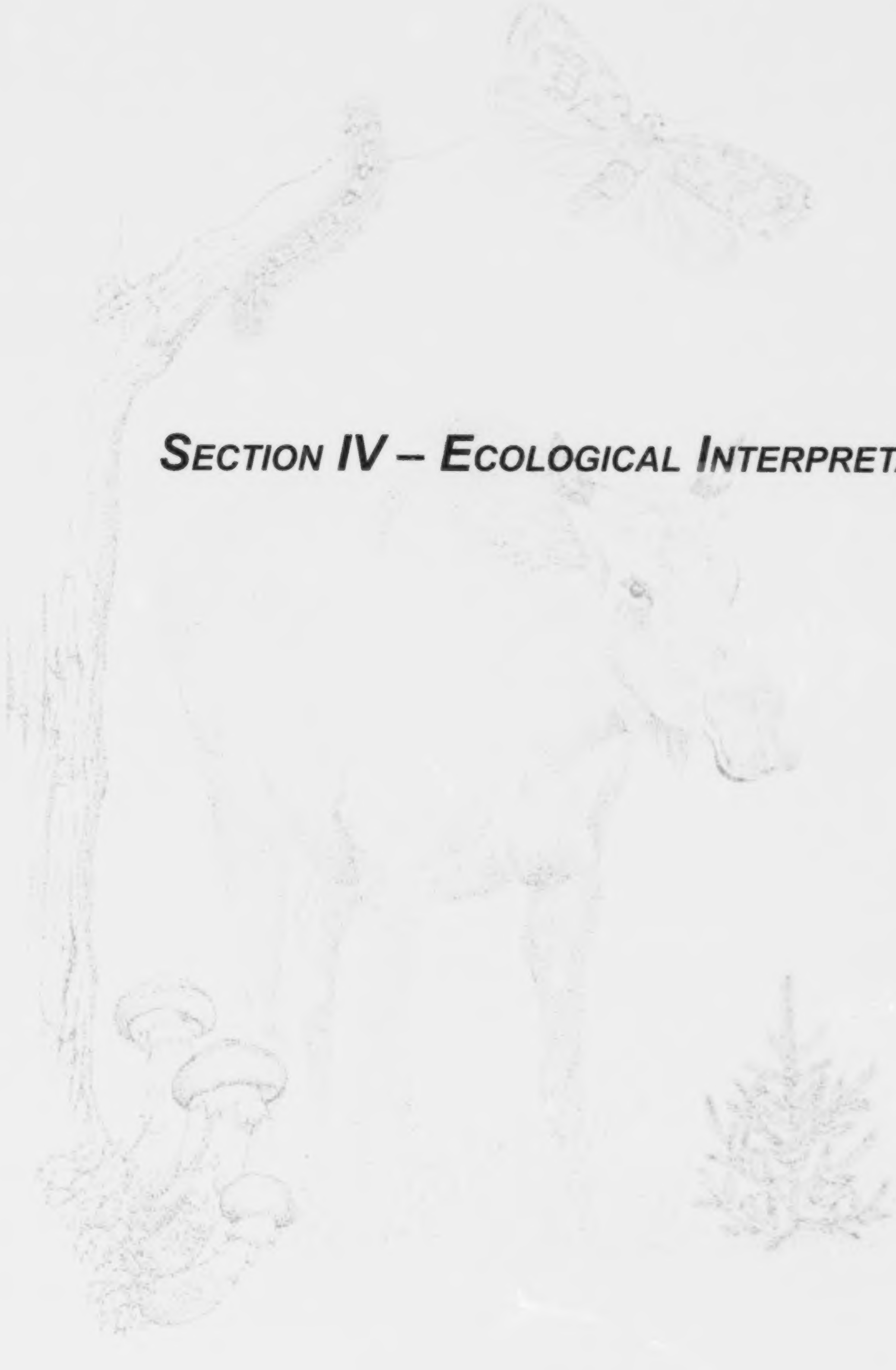
Pruning

Pruning is the removal of lower branches from standing live trees by natural or artificial means (NRC 1995). It is generally done when the desired end product is of high value (e.g. veneer logs). Pruning can also be done to improve aesthetics and interior access to a stand.

AMELIORATION

Amelioration is any operation carried out on the physical site to change one or more abiotic factors in order to improve the growth or quality of a stand (OMNR 1997c). It usually involves fertilization and/or drainage improvements. Neither of these operations would typically be required on boreal mixedwood sites which tend to be fertile and well-drained. Nutrient cycling studies in boreal mixedwoods have shown that after clearcutting, sufficient nutrient stores remain on site to sustain future growth (Morris, in prep.). Forest fertilization and drainage are not permitted on Crown land in boreal Ontario (OMOEE 1994).

SECTION IV – ECOLOGICAL INTERPRETATIONS



Section IV presents ecological interpretations that describe the interactions among trees and other plants, animals, and abiotic factors that are associated with a boreal mixedwood site. These environmental factors impact stand development and are considered specifically in the context of Ontario conditions. Management interpretations (Section VI) were developed using this information, so that they not only emulate natural disturbances and processes, but also lead towards, with a reasonable amount of confidence, the expected future stand condition. Where Ontario-specific information is lacking, these gaps have been identified and in some cases, filled with information from other jurisdictions.

The ecological information presented in this section fits within the broader ecological context presented earlier in Section II. This section:

- describes how specific environmental factors and disturbance agents influence, and are influenced by stand development, and how these agents relate to management opportunities and challenges on boreal mixedwood sites; examples focus largely on the classic successional pathway on boreal mixedwood sites (i.e. from hardwood dominated through a hardwood-softwood mixture to a softwood dominated condition)
- identifies the wildlife habitat usage for the six future stand conditions targeted by this guide

Detailed descriptions of the compositional and structural characteristics of Ontario's boreal mixedwoods are provided in Popadiouk *et al.* (in prep.).

ENVIRONMENTAL FACTORS AND DISTURBANCE AGENTS

At a landscape level, stands can be created and managed in different successional stages, and for different tree species compositions, to create a patchwork of stands that simultaneously meets multiple forest management objectives such as timber production, visual aesthetics, water quality, fisheries and wildlife habitat, and general structural, spatial, and biological diversity. Understanding the role of environmental factors and disturbance agents during natural stand development provides the foundation for identifying management opportunities and challenges related to these factors. This information can be used to create stand conditions that could help direct tree species composition and stand structure into a desired future stand condition and to avoid conditions that are undesirable.

The ecological interpretations in this section are based on the following environmental factors and disturbance agents:

- environmental factors
  - seedbed and surface conditions
  - microclimate
  - soil nutrition
  - vegetative competition
- disturbance agents (biotic and abiotic)
  - disease
  - insects
  - herbivory (mammalian)
  - wind damage
  - snow damage
  - non-stand-replacing fire

Environmental Factors

Seedbed and Surface Conditions

Different types of disturbances can produce different plant communities on boreal mixedwood sites (e.g. Nguyen-Xuan *et al.* 2000, Peltzer *et al.* 2000). This variation in species composition may result from species differences in:

- Availability of seedbeds and surface conditions (primarily soil temperature and moisture) suitable for establishment by seed and/or vegetative means (such as suckering and sprouting).
- Availability of seed sources and vegetative propagules (buds).

- Microclimatic effects on the subsequent survival and growth of seedlings and vegetative stems.

The first two factors are generally construed as the main constraints to initial establishment and are discussed here. Microclimate is also discussed as a separate topic.

The following discussion is based in large part on literature reviews by Greene *et al.* (1999), H.W. Anderson *et al.* (2001), Fleming *et al.* (2001), Groot *et al.* (2001), and McRae *et al.* (2001b).

Role of Seedbed and Surface Conditions During Stand Development

Following a stand-replacing disturbance, ample optimal seedbeds (i.e. exposed mineral soil, mixed humus and mineral soil, or thin organic layers; see Section VII) and suitable surface conditions typically exist for natural regeneration of most boreal tree species. Therefore, where establishment from seed is initially sparse, it is not usually due to a lack of suitable substrate, but rather to lethal surface temperatures and/or insufficient surface moisture in exposed microsites (assuming ample seed supply). In contrast, exposure and soil temperature conditions tend to immediately favour vegetative propagation in hardwoods (Burns and Honkala 1990).

The quality of seedbed and surface conditions for establishment may decline rapidly as vegetation colonizes the site and organic matter begins to accumulate, as follows:

- Although any harsh surface conditions are ameliorated, optimal seedbeds become scarce within five to seven years after disturbance, making establishment by seed a relatively rare event after this period for all five defining boreal mixedwood species except balsam fir (Greene *et al.* 1999).
- Vegetative propagation in hardwoods may also decline as the forest floor becomes increasingly shaded. Aspen suckering is inhibited by root zone temperatures lower than 15° C and is optimal between approximately 20° and 30° C (Maini and Horton 1966, Maini 1967).

By the stem exclusion stage, the area of suitable seedbeds has been severely reduced and tree recruitment is limited. For example:

- There tends to be fewer disturbances to the main tree canopy and favourable seedbeds are not likely to be created by uprooting of canopy trees (Lee and Sturgess 2001).
- Despite self-thinning of the overstorey, the availability of well-decayed, downed, coarse, woody debris as a seedbed may be low (Lee and Sturgess 2001); nonetheless, when available, it may represent an important recruitment medium for species such as white spruce (e.g. Lieffers *et al.* 1996b).
- If the overstorey is composed largely of hardwood tree species, annual inputs of deciduous leaf litter may be large. Intact broadleaf litter generally makes a poor seedbed because it may be prone to rapid drying, impede soil warming, and smother small seedlings (Gregory 1966, DeLong *et al.* 1997).
- Conditions are also generally unfavourable for vegetative propagation of hardwoods. Suckering and sprouting of canopy trees is suppressed by apical dominance (Burns and Honkala 1990) and broadleaf litter and overstorey shade also reduce suckering by restricting soil warming.

As stands develop into the canopy transition stage and early successional hardwoods (where present) are replaced by more shade-tolerant conifers, the input of deciduous leaf litter declines and decayed downed coarse woody debris increases (Simard *et al.* 1998). This may improve the establishment of white spruce (Lieffers *et al.* 1996b, DeLong *et al.* 1997, Simard *et al.* 1998). By the gap dynamics stage, deep rooting and very shade-tolerant balsam fir may be more successful at becoming established from seed in undisturbed microsites than the shallower rooting and less shade-tolerant spruces (Galipeau *et al.* 1997).

A mosaic of seedbed and forest floor conditions can occur at later successional stages depending on the type, size, and number of non-stand-replacing disturbances that occur:

- Single- or multiple-tree windthrow (uprooting) results in the exposure of mineral soil (Ulanova 2000), a favourable seedbed for most species.

- Snapping of hardwood stems may contribute to the provision of downed, coarse, woody debris that, once sufficiently decayed, may also serve as a suitable seedbed for some species.
- If the gap created is large enough, conditions may also be suitable for regeneration and the subsequent survival of aspen and birch (e.g. Kneeshaw and Bergeron 1999, Vasiliauskas and Chen, in prep.).

Although the abundance of individual boreal tree species may differ in different sizes of canopy gaps (Kneeshaw and Bergeron 1998), it is difficult to separate the influence of seedbed and surface conditions from other gap conditions that may also influence tree recruitment and community composition. Typically, shade-intolerant species are favoured in large gaps and shade-tolerant species in smaller gaps (e.g. Coates and Burton 1997). Observations, in the boreal forest in nearby Quebec, indicate that shade-intolerant aspen and birch are capable of establishing and surviving (i.e. undergoing self-replacement) to some extent at the gap dynamics stage. Similar observations have recently been made in northeastern Ontario (Vasiliauskas and Chen, in prep.).

- Birch, in particular, appears to have the potential to maintain itself through self-replacement in the gap dynamics stage and can be an important component on some sites (Kneeshaw and Bergeron 1998, Vasiliauskas and Chen, in prep.).
- Although observed at lower frequency and in larger gaps, aspen may also be more common in later successional stages than previously believed (Harvey and Bergeron 1989, Lavertu *et al.* 1994, Paré and Bergeron 1995, Kneeshaw and Bergeron 1996, 1998, 1999, Vasiliauskas and Chen, in prep.).

Management Opportunities and Challenges

With respect to natural regeneration, boreal mixedwood management should ensure that:

- Seedbeds and surface conditions exist that selectively promote the establishment of desirable tree species and/or inhibit the establishment of undesirable species.
    - The type and severity of silvicultural disturbance (e.g. harvesting and site preparation) can be varied.
- The presence of the desired conditions coincides, in both time and space, with the availability of viable seeds and/or vigorous vegetative reproduction to promote the desired species and discourage any undesirable species.
    - Coordinating the creation of sufficient suitable, well-spaced microsites with the availability of seed and/or asexual buds can be accomplished by understanding the reproductive characteristics of a species and planning accordingly.

Trends during natural stand development indicate that the greatest cover of suitable seedbeds occurs following a disturbance (Greene *et al.* 1999). Harvesting generally causes some disturbance to the forest floor, but the quantity and quality of available seedbeds can be improved, where necessary, by site preparation (Wagner and Colombo 2001). When the goal is to establish shade-tolerant conifers from seed prior to overstorey harvest, understorey scarification will likely be required to create sufficient seedbeds (Stewart *et al.* 2000).

It has been suggested that large forest openings (greater than one hectare) may be required for good vegetative propagation in aspen (H.W. Anderson *et al.* 2001)[1]. Additional forest floor disturbance is generally not necessary (Davidson *et al.* 1988). However, removing organic matter may still enhance suckering (e.g. Kabzems 1996), and may even be necessary on sites with insulating vegetation or thick duff layers (H.W. Anderson *et al.* 2001). Care should be taken to ensure that aspen roots are not severely damaged by any method of site preparation. For example:

- On sensitive sites, rutting and compaction of the forest floor and surface soil layers may inhibit aspen suckering or subsequent growth (e.g. Shepperd 1993, Bates *et al.* 1993, Stone and Elioff 1998, Smidt and Blinn 2002). Winter operations, use of low ground pressure harvesting equipment, and equipment that can widen the distance between trails may be advised on such sites.

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[1] Aspen regeneration is reduced but not altogether inhibited in smaller forest openings.

- Stump sprouting in birch, also induced by the loss of apical dominance during harvesting, can be reduced by severe fire or where stumps are damaged during forest operations (Greene *et al.* 1999).

In addition, once objectives for suitable seedbed cover and surface conditions are achieved, consideration must also be given to the availability and/or vigour of seed and vegetative propagules.

Seed production and dispersal characteristics of boreal tree species are summarized in the autecology tables in Section VII. For all non-serotinous species, additional contributions of viable seed from the soil seed bank should be considered negligible because dormant seed of these species generally does not survive longer than one year (Greene *et al.* 1999, Fleming *et al.* 2001). Semi-serotinous cones render current seed production less critical for black spruce regeneration.

Operational considerations when planning for natural regeneration from seed may include:

- Timing (year, season) of harvesting and/or site preparation operations that create suitable seedbeds to coincide with periods of high seed production and dispersal of the target species.
- Seed dispersion distances (distance from a seed source) required for full or satisfactory stocking. Seed dispersion distances may define:
  - The maximum size and shape of harvested areas.
  - The required density and spatial arrangement of healthy, reproductively mature, windfirm seed trees.

The seed dispersion distances in Section VII assume that seed is being dispersed from intact forests into large clearings. Effective seed dispersion from small patch or strip sources may differ because seed dispersal varies with wind speed which is, in turn, a function of exposure. Because of a lack of information about seed sources and dispersal within openings of different sizes, the following may be used as general rules (Greene *et al.* 1999):

- Seed fall from patch or strip sources typically shows a gradual decline within one tree height from the source edge, followed by a rapid decline thereafter.
- Strip cuts 50 to 100 metres in width may effectively eliminate seed dispersal constraints.
- Patches of residual seed trees, approximating five percent of the total area, may provide for adequate seed dispersal in large clearings, assuming that blowdown will not be a problem (stocking is rarely adequate beyond 75 metres into large openings).
- Of the five defining boreal mixedwood species, only black spruce has some potential to successfully colonize large burns or cutover areas from seed in the absence of live residual seed trees (Greene *et al.* 1999). Black spruce seed may remain viable in semi-serotinous cones for three to four years in standing trees or in slash (Schoenike and Hanson 1954, Haavisto 1979).

Densities and spatial arrangements of seed trees required for full or satisfactory stocking can be estimated from the information contained in the autecology tables (Section VII), and the general rules listed above. Estimates may need to be adjusted for site quality or increased mortality to young seedlings from drought or frost.

Factors affecting the stocking of aspen and birch by vegetative means are shown in Table 1. Operational considerations may include:

- Timing harvesting and/or site preparation operations to coincide with the anticipated maximum vigour of a target species (stand age, season) or the anticipated low vigour of undesirable species.
- Using clonal expansion distances for vegetative propagules (where applicable) to define the density and spatial arrangement of parent trees that would allow for full or satisfactory stocking.

Birch is not capable of clonal expansion, but can replace itself with basal sprouts (Greene *et al.* 1999). Stocking of birch from stump sprouts depends on the representation and age of birch in the stand prior to the disturbance. Sprouting potential is limited after parent trees reach 70 years of age (Table 1).

For aspen, most root suckers are located within five metres of the nearest bole, with dispersion declining rather abruptly within another 10 metres (Greene *et al.* 1999). Assuming a clonal expansion distance of five and 10 metres, the density of uniformly

Table 1. Factors affecting the stocking of trembling aspen and white birch by their most common method of vegetative reproduction.

Species	Mode of Vegetative Reproduction	Age Effects on Vegetative Reproduction	Seasonal Effects on Vegetative Reproduction	Clonal Expansion Distance (metres)
Trembling aspen	root suckers	stand and tree age generally has little effect, except that suckering potential may perhaps be reduced in very young stands or in decadent stands [a] [b]	sucker initiation and initial sucker density may not vary appreciably with season of cut [e] *however,* to maximize survival of suckers, cut in autumn [e] *and* to minimize survival of suckers, cut in early summer after leaf flush [e]	6–10, typical [c] 21, maximum [c] most expansion probably occurs within 5 metres of the bole, with a rapid decline in expansion within the next 10 metres [c]
White birch	stump sprouts	approximately linear decline in sprouting capacity with age [a] sprouting potential may be effectively limited after parent trees reach 70 years of age [a]	sprouting is believed to be enhanced if trees are cut in the dormant season and reduced if trees are cut in May–June [d]	not applicable

Sources: *a*, Zasada *et al.* 1992; *b*, Lavertu *et al.* 1994; *c*, Greene *et al.* 1999; *d*, Peterson *et al.* 1997; *e*, Bell *et al.* 1999.

distributed parent trees required for full stocking is calculated to be 400 and 100 stems per hectare, respectively. The latter estimate supports a previous recommendation that full stocking of aspen is likely to be achieved by 100 to 120 mature stems per hectare (Davidson *et al.* 1988).

Root sucker distribution of aspen has been insufficiently investigated (Greene *et al.* 1999). Therefore, caution is advised when determining the density of uniformly distributed aspen trees required for full stocking when the pre-disturbance density of aspen is low. The suckering potential of aspen from different geometries of canopy openings is likewise not well understood (Greene *et al.* 1999), although it is expected to decline with decreasing gap size or increasing density of residual trees (Groot *et al.* 1997, MacDonald 2000, MacDonald and Thompson, in prep., Kabzems 1998).

Microclimate

Overstorey tree canopy cover and/or vegetative cover can be varied to create microclimatic conditions that differentially favour, or discourage, the establishment, survival, and growth of individual tree species. The intent is to mimic what occurs during natural stand development on boreal mixedwood sites, where changes in canopy cover and microclimate are associated with distinct changes in tree species composition and resulting stand structure (Chen and Popadiouk 2002).

The following discussion is based on a review by McKinnon and Kayahara (in prep.).

Role of Microclimate During Stand Development

In the absence of vegetation, microclimate at the stand initiation stage can be described as an exposed microclimate characterized by: abundant light; extremes in air temperature (high daily maximum temperatures, low daily minimum temperatures, and potential frost risk); potentially high wind speeds; and relatively high evaporative demand (e.g. Groot and Carlson 1996, Tanner *et al.* 1996, Carlson and Groot 1997, Groot *et al.* 1997, Groot 1999). Surface soil temperatures are likely to be warmer than those in the intact forest but the difference may be less pronounced wherever a thick forest floor remains after disturbance. In an exposed microclimate, early successional shade-intolerant species such as trembling aspen and white birch are favoured over more shade-tolerant species such as white spruce, black spruce, and balsam fir (environmental requirements and tolerances of these species are indicated in the autecology tables, Section VII).

As a vegetative canopy develops, the exposed microclimate of a disturbed area can become rapidly altered:

- Initially, microclimatic conditions that are unfavourable to some tree species may be ameliorated to some extent as vegetation colonizes a site. Vegetation may lower vapour pressure deficits, buffer air temperature extremes, and provide protection from frost (e.g. Groot *et al.* 1997).
- Where developing vegetation becomes substantial, it may compete with tree species for light, soil moisture, and nutrients and may also shade the soil surface sufficiently to reduce soil temperature (Carlson and Groot 1997, Groot *et al.* 1997, Groot 1999, Staples *et al.* 1999) .
- Because of fast initial height growth rates under high light conditions, shade-intolerant tree species (particularly aspen and birch of sucker and sprout origin) are less likely to be overtopped and suppressed by vegetation than slower growing shade-tolerant conifers; early dominance gained by shade-intolerant species generally carries through to later stand development stages.

Microclimate beneath the main tree canopy at the stem exclusion stage (under a fully closed overstorey) is characterized by: a relative lack of air temperature extremes; low light levels, wind speeds, and evaporative demands; reduced frost risk; and relatively low soil temperatures (Groot and Carlson 1996, Carlson and Groot 1997, Groot 1999). Shade-tolerant species are favoured due in large part to light limitations. However, during the early part of this stage, light beneath the main tree canopy can sometimes reach levels low enough to severely compromise the survival of even the most shade-tolerant tree species, e.g. as low as four percent beneath juvenile aspen canopies (Pinno *et al.* 2001). Light levels tend to increase during the stem exclusion stage after some self-thinning of the overstorey has occurred (Lieffers and Stadt 1994, Pinno *et al.* 2001).

Table 2 shows the approximate amount of light available beneath closed aspen and birch canopies during the latter part of the stem exclusion stage to the early canopy transition stage after some self-thinning of the overstorey has taken place.

In Ontario, light levels beneath mature closed canopies of aspen (six to 23 percent full sunlight) tend to be insufficient to marginal for survival of understorey shade-tolerant conifers (approximately 25 percent or more full sunlight is required, after Greene *et al.* 2002). Light levels will be even lower where understorey conifers are further shaded by understorey vegetation. Light attenuation by overstorey and understorey vegetation combined may sometimes result in light levels at or near the forest floor as low as two to six percent (Constabel and Lieffers 1996, Messier *et al.* 1998, Groot 1999, Aubin *et al.* 2000). In such cases, light constraints will limit seedling survival.

Comparable information is lacking on light conditions beneath mature closed canopies of white birch in Ontario (Table 2).

Table 2. Light levels beneath aspen and birch stands during the late stem exclusion stage to early canopy transition stage.

Canopy Type	Range of Light Availability, % Full Sunlight	References
Trembling aspen overstories	6–23%, Ontario	Carlson and Groot 1997, Groot *et al.* 1997, Groot 1999, MacDonald and Thompson, in prep.[a]
	8–13%, Quebec	Messier *et al.* 1998
	18–32%, prairie provinces	Lieffers and Stadt 1994, Chen *et al.* 1997; see also Stewart *et al.* 2000[b]
	14–28%, British Columbia	Tanner *et al.* 1996, Comeau 2001
White birch overstories	Ontario data not available	Ontario data not available
	12–19%, Quebec	Messier *et al.* 1998
	10–18%, British Columbia	Comeau *et al.* 1998

Light measurements were taken below the main tree canopy but above any understorey vegetation. Stands are all mature stands greater than 35 years of age.

a. In MacDonald and Thompson (in prep.), it was not clear that light levels were unaffected by understorey vegetation. However, any effect of understorey vegetation was likely to be relatively small because light levels were measured at 1 m height and understorey vegetation was not abundant.

b. In Stewart *et al.* (2000), light levels under mature aspen in Alberta were 19 to 34 percent, but stand age was not specified.

Source: McKinnon and Kayahara (in prep.)

Both canopy transition and gap dynamics stages of stand development are characterized by the presence of canopy gaps (Chen and Popadiouk 2002). As a result, the microclimate beneath the canopy during these stand development stages tends to be characterized by: moderate light levels; and intermediate air and soil temperatures, wind speeds, and vapour pressure deficits between those typically encountered at the stand initiation stage and stem exclusion stage (e.g. see canopy cover effects in Groot *et al.* 1997). Relative to open areas, the partial canopy cover associated with tree-fall gaps may, therefore, reduce the frequency and severity of night frosts (Groot and Carlson 1996, Man and Lieffers 1999). Surface soil moisture may also be conserved better in gaps than in fully exposed areas although the absolute amount of soil moisture may be less (Groot *et al.* 1997).

Given the variety of gap sizes possible, generalizations on the amount of light transmitted through the overstorey during the canopy transition and gap dynamics stages are not possible for natural stands. However, there is a general trend for the majority of gaps to be relatively small through the transition stage, with larger gaps (and higher light levels) becoming more common once stands reach the gap dynamics stage (Kneeshaw and Bergeron 1998). In general, shade-tolerant species tend to be favoured under low light conditions in smaller gaps, and shade-intolerant species are favoured by high light and other conditions in large gaps (Coates and Burton 1997). However, understorey vegetative competition and substrate limitations may still prevent successful establishment of new trees even when gap sizes are otherwise favourable. For example, large gaps may be dominated by shrubs even where they are otherwise favourable for aspen if these gaps formed gradually as a result of eastern spruce budworm (balsam fir trees attacked by budworm remain standing for some time following death) (Kneeshaw and Bergeron 1998).

Management Opportunities and Challenges

When managing for microclimate, the main objectives are:

- Amelioration of harsh microclimatic conditions during the stand initiation stage, particularly on frost-prone sites (Groot and Carlson 1996, Man and Lieffers 1999) and hot or dry sites (Childs and Flint 1987).
- Limiting competition from more aggressive and undesirable tree species (e.g. aspen, wherever it forms a higher than desired proportion of a stand) or ground vegetation (e.g. Lieffers and Stadt 1994, Groot *et al.* 1997, Groot 1999, Zasada *et al.* 2001), thereby reducing costs associated with vegetation management.
- Creating light levels conducive to the survival and growth of desirable regenerating tree species.

All three objectives may be achieved by targeting specific light levels by varying overstorey tree canopy cover and using vegetation management as required to maintain target light conditions at seedling or sapling height. It is possible to use light to manage for other microclimatic factors because these other factors relate closely to light conditions (light is used as an integrated index of canopy influence [Horn 1971]). Likewise, the amount of understorey vegetation cover increases with increasing overstorey light transmittance on any given site (e.g. Lieffers and Stadt 1994, Constabel and Lieffers 1996, Groot *et al.* 1997).

Microclimate Amelioration

A reduction in light availability to 50 to 75 percent full sunlight may:

- Provide adequate frost protection to susceptible tree seedlings (particularly white spruce) (Groot and Carlson 1996, Man and Lieffers 1999).
- Be sufficient to provide susceptible tree seedlings (particularly white spruce) with adequate physiological relief from high vapour pressure deficits (Marsden *et al.* 1996, Groot *et al.* 1997, Man and Lieffers 1999), although this reduction in vapour pressure deficits is not well defined under field conditions.

Limiting Competition

A reduction in light availability to 40 to 60 percent full sunlight may be required to reduce the density of aspen suckers to 50 percent of that in clearcuts (Groot *et al.* 1997, MacDonald 2000). A reduction to 25 percent of full sunlight may be required to reduce the density of suckers to 10 percent of that in clearcuts (Groot *et al.* 1997)[2].

Because the latter treatment may, in some cases, still leave more than 10,000 stems of aspen per hectare, partial canopy removal methods may have to be augmented with some cleaning, even when a mixture of conifers and hardwoods is the goal. However, less cleaning will be required than in clearcut areas.

A reduction in light availability to 40 to 50 percent full sunlight may be required to successfully suppress light-demanding, non-crop competitors such as Canada blue-joint and fireweed (*Epilobium angustifolium*) in drier climates or on drier sites (Lieffers and Stadt 1994).

In contrast, the feasibility of using overstorey canopy shade to successfully suppress more shade-tolerant vegetation such as beaked hazel and mountain maple on fresh to moist fertile sites in Ontario is questionable (Groot *et al.* 1996, 1997, Groot 1999).

Maintaining Survival and Growth

Targeting, maintaining, or creating light levels greater than 25 percent of full sunlight may ensure the survival and eventual response to release of understorey shade-tolerant conifers (Ruel *et al.* 2000a, Greene *et al.* 2002). Prescriptions for promoting shade-intolerant hardwoods do not generally involve dense overstorey shading.

Towards the end of the self-thinning (stem exclusion) stage in aspen dominated stands, light levels may approach levels suitable for underplanting (approximately 25 percent or more full sunlight (after Greene *et al.* 2002) (Table 2). Alternatively, partial canopy removal methods may be used to create these conditions. In either case, it is likely that some vegetation control will be required to maintain adequate light levels at seedling height. It is not known if light levels under birch in Ontario may be suitable for underplanting. Suitable light conditions could be created through partial overstorey removal.

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[2] The configuration of forest openings can also be important (Groot *et al.* 1997).

Beyond minimum light levels required for survival, higher light levels that allow for "acceptable" levels of growth (whether optimal or suboptimal) may be targeted. The standards for "acceptable growth" will vary with management objectives for a given stand:

- When maximum timber production is the primary objective, silvicultural systems are generally prescribed that result in no, or minimal loss of growth to regenerating trees.
    - In this case, either an exposed environment is maintained, or any residual tree canopy is removed before the growth of regenerating trees is negatively impacted. Growth rates are considered optimal or near optimal, for the species in question.
    - In boreal Ontario, conventional clearcut and shelterwood silvicultural systems (with final removal) may fall within this category[1].
- When the primary forest management objective is not maximum timber production, silvicultural systems may in some cases be applied that result in the loss of growth of regenerating trees because of long-term, persistent, overstorey shading.
    - In this case, the goal, with respect to regeneration, is to ensure that trees survive (25 percent or more full sunlight for shade-tolerant species) and exhibit acceptable (suboptimal) levels of growth.
    - Shelterwood silvicultural systems with extended overstorey retention and selection silvicultural systems fall within this category.

Where some loss of tree growth is anticipated, the growth loss may be approximated based on the light-growth relationship of the species of interest (for the five defining boreal mixedwood species, see Lieffers and Stadt 1994, Wright *et al.* 1998, Groot 1999, Duchesneau *et al.* 2001). Data for Ontario are sparse (Groot 1999) and caution is advised when applying these equations because light-growth relationships may vary with: plant size (e.g. Duchesneau *et al.* 2001, Claveau *et al.* 2002); climate (Wright *et al.* 1998); site quality (Canham *et al.* 1996); slope, aspect, and other topographic features (Chen *et al.* 1999); and the species composition of the overstorey (evergreen versus deciduous). Genetic differences among families may also play a role. Generally, minimal acceptable height growth rates for shade-intolerant species are expected to be higher than those for more shade-tolerant species because, for a given height growth rate, survival tends to be lower for shade-intolerant species (Kobe *et al.* 1995, Kobe and Coates 1997).

Soil Nutrition

Soil nutrition comprises the total nutrients on a site, nutrient cycling or turnover, and their subsequent availability to plants. If short- and long-term site productivity on boreal mixedwood sites is to be maintained, management practices should not compromise soil nutrition.

The following discussion is based on reviews by Morris (in prep.) and Kayahara (in prep. b).

Role of Soil Nutrition During Stand Development

Soil nutrient dynamics change throughout stand development. During a stand-replacing fire there is an increased release of nutrients accompanied by some volatilization of nutrients, and a rise in pH with mineralization of the forest floor. Likewise, immediately following stand-replacing windthrow, there is an increased release of nutrients and a rise in pH from the acceleration of forest floor mineralization in warmer, newly exposed microsites. In both cases, nutrients are initially highly soluble and, therefore, mobile. The potential for nutrient

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[1] Residual trees in clearcuts exert little influence on the microclimate because of the low density of residual trees left behind (25 stems per hectare according to the natural disturbance pattern guidelines [OMNR 2001b]), and the relatively short canopy heights in northern Ontario. The sheltering effect of mature aspen extends slightly more than one dominant tree height in length into an opening (Groot *et al.* 1997, Kneeshaw and Bergeron 1998), that in parts of northern Ontario may only be about 19 metres (Groot *et al.* 1997).

"leakage" from a site can be high. However, most of the nutrient release may be taken up and retained by early successional, nutrient-demanding plants during subsequent revegetation of the site (Vitousek 1977, Boring *et al.* 1981, Prescott *et al.* 2000, McRae *et al.* 2001a).

Deciduous hardwood trees may accelerate nutrient cycling throughout the stand initiation stage and into the subsequent stem exclusion stage:

- Aspen tends to act as a nutrient pump, contributing large amounts of nutrient-rich leaf litter and nutrient-rich woody boles. Aspen is deep rooted, exhibits luxury consumption, and tends to have an inefficient internal nutrient cycling mechanism (Alban *et al.* 1978, Jones and DeByle 1985, Pastor 1990).
- Birch has also been recognized for its positive effect on soil nutrition, which includes a reduction in acidity and an increase in calcium availability (Troth *et al.* 1976, France *et al.* 1989).
- The relatively high pH (low acidity) associated with deciduous leaf litter facilitates nutrient cycling (Perala and Alban 1982, Jones and DeByle 1985).

At the canopy transition stage, nutrient cycling tends to decrease as the softwood component increases. This is because the needle litter of black spruce, white spruce, and balsam fir has a high nutrient immobilization potential (nutrient concentration is low and the needles are slow to decompose relative to hardwood litter). Thus, nutrient cycling in hardwood leading or softwood leading stands (characteristic of the canopy transition stage) tends to be less rapid than in hardwood dominated stands (Pastor *et al.* 1987).

As stands develop into the gap dynamics stage and the conifer component increases, nutrient availability declines further. This is especially evident for nitrogen, but also for other macronutrients and micronutrients as well (Pastor *et al.* 1987). Reduction in nutrient availability is characterized by decreases in the nutrient concentration of litterfall, decreases in soil respiration, increases in the soil carbon to nitrogen (C:N) ratio, and increases in forest floor mass, accompanied by a change in forest humus form from mull/moder to a more acidic mor humus (Krajina 1969, Troth *et al.* 1976). The mor humus can develop into a thick (insulating) surface organic layer that may further limit nutrient cycling by reducing upper soil temperature (Heilman 1966). The reduction in nutrient availability that tends to occur during later stages of stand development can lead to slow tree growth and possibly an increased susceptibility to insects and diseases (Pastor *et al.* 1987).

It has been suggested that the sequence of forest floor succession described above (i.e. from mull/moder humus to mor humus forms) may lead not only to a short-term reduction in nutrient turnover, but also to a long-term reduction in turnover that is associated with soil acidification and, possibly, paludification. One hypothesis is that in the absence of disturbance, late successional stands on mesic sites may show an increase in the cover of *Sphagnum* moss. *Sphagnum* is acidic, very slow to decompose, and exhibits high water retention. The buildup of a *Sphagnum* organic layer may begin the process of paludification (Tallis 1983). This hypothesis is supported by chronosequence evidence from Ontario's Hudson Bay Lowland (Klinger 1996, Klinger and Short 1996). Currently, evidence for the occurrence of such a scenario on boreal mixedwood sites is weak. In Ontario, if paludification occurs at all, it will probably be a concern only on moister boreal mixedwood sites within Ecoregion 3E.

Although differences in nutrient cycling between hardwood and softwood litter are well documented, the effect of stand composition on the underlying mineral soil is much less clear. Hardwood and softwood dominated stands growing on similar sites appear to have distinctly different plant communities and humus form properties but reported effects on mineral soil are inconsistent (Binkley 1995, Kayahara, in prep. b). Because boreal mixedwood sites are generally rich sites, it may be that the large nutrient stores and high buffering capacity of these soils may delay the development of any differences in soil properties between hardwood and softwood dominated stands (Kayahara, in prep. b).

Management Opportunities and Challenges

Three important considerations for forest managers concerned with maintaining the short- and long-term productivity of a site are:

- nutrient removal from harvested sites
- potential for soil rutting and compaction
- potential for site productivity decline and paludification

Nutrient Removal from Harvested Sites

Nutrients may be lost from a site as a result of some forestry operations. Full-tree logging has a particularly high potential for compromising the nutrient capital of a site, especially wherever a large number of deciduous hardwood trees with nutrient-rich litter, like aspen and birch, are removed. However, because the rich soils characteristic of boreal mixedwood sites have large nutrient stores, such nutrient loss may be of little overall concern, at least in the short term (Morris, in prep.).

Potential for Soil Rutting and Compaction

Soils on boreal mixedwood sites tend to be relatively fertile and resilient, but they can be susceptible to both rutting and compaction. Fine soils are generally the most susceptible, particularly in a wet-to-saturated state. Rutting and compaction may increase soil bulk density and decrease porosity, and thereby alter water infiltration, soil hydraulic conductivity, and lateral water flow. Soil compaction can negatively impact root suckering capacity in aspen and excessive site disturbance may negatively impact all tree species by impeding root penetration and development and altering gas exchange between roots and soil (Archibald *et al.* 1997). Approaches for mitigating impacts on these soils are provided in OMNR (1997c).

Declining Site Productivity and Paludification

Declining soil fertility, associated with the development of a softwood dominated condition, may potentially be of concern in the short- and long-term management of boreal mixedwood sites. In the short term, silvicultural prescriptions that increase the residency time of hardwoods on a site, while simultaneously ensuring adequate conifer regeneration and growth, may improve nutrient cycling efficiency.

Any differential effect that tree species may have on soil nutrition may be particularly important for boreal mixedwood sites where hardwoods and conifers grow in pure stands or in mixtures. If a hardwood dominated condition ameliorates soil nutrition, or if a softwood dominated condition at the gap dynamics stage causes soil acidification or begins the process of paludification, resource managers may want to consider some form of shifting between pure and mixed stands of hardwoods and softwoods, combined with prescribed burning. This may maintain greater nutrient availability and delay or minimize any potential decline in inherent site productivity.

Vegetative Competition

Early successional plant species can individually and collectively compete with conifers for resources such as light, moisture, nutrients, and above- and below-ground growing space (Radosevich and Osteryoung 1987, Lautenschlager 1999). Physical damage such as smothering or leader-whipping of the conifer component by non-crop vegetation is also a form of inter-specific competition and interaction that can affect the survival and growth of conifers.

Combinations of plants that thrive in early successional stages are often well-suited to dominating sites following harvesting or wildfire because of their reproductive capabilities, response to disturbance, and ability to survive and grow under harsh environmental conditions characteristic of exposed areas (Halpern 1989). Plant species with high reproductive capabilities and rapid juvenile growth rates are likely to be more aggressive competitors than species with low reproductive capabilities and slower growth rates. Those species able to produce seed in sufficient quantities relatively early in their life cycle also have a competitive advantage over species producing seed later (Zasada *et al.* 1988). The severity of competition experienced by boreal conifers on mixedwood sites varies with the competing species and increases with an increasing abundance of competitors (Lautenschlager 1995, 1999, Wagner *et al.* 1999).

The reproductive characteristics of plant species that affect their competitiveness include: the age at which the plant is capable of producing viable seed, frequency and abundance of sexual reproduction, seed longevity and viability, seed germination requirements, and the ability of the plant to reproduce vegetatively. Details of the autecology of competing species can be found in Section VII.

Under a closed forest canopy with very low light levels, the majority of the energy of the competing plant is directed at the survival of the parent plant, and few resources are transferred or expended for reproduction. As the main canopy is removed, non-crop species rapidly expand in size and number to quickly dominate a site. Individual plants that survive a disturbance often respond by increasing the size of the parent plant or by rapidly producing seed, thereby allowing for potential colonization of adjacent disturbed areas. Species that reproduce via wind-borne seed are capable of colonizing recently disturbed areas from some distance (Haeussler and Coates 1986). For example, Qi and Scarratt (1998), studying seed bank dynamics in a boreal mixedwood forest in northwestern Ontario, found that on clearcut sites, the seeds of sedges and grasses increased from less than one to 14 percent of the seed rain in the second post-harvest year.

Plants species that are seemingly rare or absent in mature forest stands may also become established from buried seeds (seed banking) and quickly dominate the pioneer vegetation community following disturbance and removal of the overstorey canopy. The composition and seed densities of seed bank species will vary greatly from site to site. Large amounts of banked seeds are usually present in the litter layers of boreal mixedwoods. The response to disturbance of seed banking species depends on the relative number and depth at which stored seeds are buried in the upper soil horizons. As buried seed depth (which is partly a function of stand age) increases, the amount of banked seed generally increases. At operational rates, commercial herbicides do not decrease the viability of seeds in the forest floor seed bank (Morash and Freedman 1989).

Little is known about seed bank dynamics and their direct contribution to the establishment of competitive non-crop vegetation in the boreal mixedwood forests of Ontario. Qi and Scarratt (1998) studied the effects of different harvesting methods on seed bank dynamics in a boreal mixedwood in northwestern Ontario. They found that while the harvesting operation altered the distribution of the seeds in the soil profile, it had no effect on the total number of species present in post-harvest seed banks or understorey vegetation. Many seeds of sedges, graminoids, and some herbs were found in the upper mineral soil horizon, indicating significant longevity.

Vegetative reproduction is generally of greater importance than sexual reproduction in the rapid recovery of vegetation immediately following a disturbance in boreal Ontario. Vegetative reproduction has a distinct advantage over seed regeneration because it is not dependent on seedbed conditions and the sprouts or suckers have the root system of the parent plant available as a source of food reserves and water supply. However, the species must have been present on the site prior to the disturbance. Methods of vegetative reproduction include sprouts, layers, underground stems (rhizomes), and root suckers. Boreal mixedwood sites are typically dominated by hardwoods that establish vegetatively soon after major disturbances such as clearcutting (Perala 1989).

Most woody shrub species also employ some form of vegetative reproduction strategy in addition to the production of seed. Boreal mixedwoods contain a high diversity of shrub species relative to other boreal forest types. Mixedwood stands often contain several layers of shrubs of different heights. Shrubs may be arranged as a somewhat continuous canopy, in more open stands, or in clumps and patches associated with canopy gaps. This abundant shrub understorey, when present, can affect stand development.

Role of Vegetative Competition During Stand Development

Light is thought to be the most limiting resource for conifer seedling growth (Jobidon 1994). Grasses and sedges require high light levels for optimum growth and seed production, and have generally high moisture and nutrient requirements. Low light levels at the forest floor in most boreal mixedwoods during the summer season are probably the main factor controlling the abundance of graminoids on boreal mixedwood sites (Constabel and Lieffers 1996). These species respond vigorously to most disturbances and can become a severe competition problem for conifer crop trees, especially on rich, moist sites.

Wagner *et al.* (1996) documented significant reductions in light below heights of 60 centimetres above the ground and below the grass and herb layer. Shropshire *et al.* (2001) studied the effect of early successional boreal plants on light reduction. During the second growing season, increasing crown cover of Canada blue-joint and large-leaved aster (*Aster macrophyllus*) had the largest influence on the decrease in light. Herbaceous vegetation control was determined to be most important in the first two years after planting, and stem diameter and volume loss from competition were proportional to the number of years without vegetation control.

Seasonal variations in light can be particularly high in understories of boreal mixedwood stands that have an abundant overstorey component of hardwoods. Although light transmission through the tree canopy can vary considerably in mixedwoods, light transmission to the forest floor tends to be very low in the summer regardless of overstorey canopy cover. This is because mixedwood stands with relatively open canopies tend to support a high cover of understorey shrubs (Constabel and Lieffers 1996).

Herbs in boreal mixedwoods employ different leaf strategies to take advantage of seasonal light conditions. Many are "summer green"; they tend to be tall to take advantage of as much light as possible, have high photosynthetic efficiency in early to mid-summer, and are more responsive to changes in temperature and light regime than shrubs. Low, biennial, or evergreen herbs and semi-shrubs, such as goldthread (*Coptis trifolia*), and twinflower (*Linnaea borealis*) respectively, are able to photosynthesize despite the cooler temperatures in the spring and fall and take advantage of the greater amount of light in these seasons (Landhäusser *et al.* 1997).

Shrubs can be classed as tall or low depending on their usual maximum height. The degree of development of these shrub layers depends on the amount of light transmitted by the higher canopy layers (e.g. dense, pure aspen canopies transmit more light than pure conifer canopies). The amount of light radiating through the canopy to the forest floor changes over the life of a stand. In early succession, during the initiation stage, light levels are relatively high until canopy closure. Lowest light levels in the life of a stand occur after canopy closure (stem exclusion stage). In mixedwoods, light levels gradually increase as a stand matures and canopy gaps form (Lieffers 1995). Because light levels tend to be higher in older stands, many such stands support dense, multi-layered, shrub communities.

Since the amount of light transmitted by deciduous canopies varies with the season, there are opportunities for understorey shrubs to use different photosynthetic strategies. Most tall shrubs, such as mountain maple and beaked hazel, are summer green and tend to be adapted to low light conditions. Their photosynthetic capacity peaks in the summer months. In contrast, low evergreen shrubs, such as blueberries (*Vaccinium* spp.) or Labrador-tea (*Ledum groenlandicum*), are adapted to low temperatures and are able to take advantage of the extra light available in spring and fall by photosynthesizing in these seasons (Lieffers 1995).

Shrubs in mixedwood forests tend to respond vigorously to increases in light regime and temperature. As a mixedwood stand ages, openings in the canopy caused by tree mortality can rapidly fill with shrubs and hardwoods, mainly by suckering, which will often reduce or exclude conifer regeneration unless the openings are large. Openings caused by the mortality of conifers affected by the eastern spruce budworm often release woody shrubs such as mountain maple. These patches result in increased vertical and horizontal structure in mixedwood stands and enhance habitat and biodiversity characteristics. Although the effects of large-scale windthrow events on shrub communities in boreal mixedwoods are not well documented, it is likely that shrub populations will be enhanced in the openings which these events create.

Management Opportunities and Challenges

While many treatment methods for limiting the growth and spread of these vegetation complexes have been explored, efficacy has varied widely due to:

- the intensity and severity of the disturbance
- the number, health, and structure of the competing non-conifer vegetation on the site
- soil and site conditions
- timing of forestry activities

Response of a plant species to a silvicultural treatment depends primarily upon the reproductive mechanisms of that species.

The purpose of vegetation management is not to eliminate all competing plants but rather to temporarily direct more of the site's resources into fulfilling the management objective. With the exception of grasses and sedges, herbs rarely provide significant competition for light resources for the establishment of crop trees in boreal mixedwoods. Partial cover provided by these species can be beneficial for the establishment of white spruce by providing frost protection. However, lesser plants may compete with crop trees for nutrients and moisture, and some degree of vegetation control may be required. Control of competing vegetation can be achieved with ground or aerial herbicide applications. Lautenschlager and Sullivan (2002) provide a very thorough review of the effects of herbicide treatments on biotic components in regenerating northern forests. As an alternative to herbicides, Lieffers (1995) and others promote partial canopy removal methods as a control strategy for competing species. With these treatments it is necessary to maintain sufficient overstorey canopy cover (shading) to reduce the abundance of understorey plants.

The post-disturbance survival of plant species with underground vegetative reproductive propagules, such as rootstocks or rhizomes, is affected by the nature and degree of the disturbance, the depth of the rooting material in the soil, and the ability of the below-ground propagules to survive physical damage and dissection. Deep burning fires are generally required to kill these species. Mechanical site preparation is less effective than other strategies in controlling these species, but may provide an option in certain circumstances. Canada blue-joint, for example, is able to survive and re-sprout if dissected segments are at least two nodes in length (Lieffers 1995).

In boreal mixedwoods, control of competing woody shrub species is usually needed for conifer establishment. Mechanical disturbance such as full-tree skidding tends to break the main stem of shrubs and flatten their canopies, a particularly effective control technique for mountain maple and beaked hazel. However, disturbance from mechanical site preparation can increase the abundance of species such as wild red raspberry (Zasada and Grigal 1978, Hauessler and Coates 1986) and promote the formation of many new suckers. Control can be achieved with ground or aerial herbicide applications. Maintaining sufficient overstorey canopy cover can sometimes help to reduce the abundance of shrubs in the understorey.

Bell and Newmaster (2002) studied the effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest of northcentral Ontario. Their study sites were clearcut using full-tree harvesting methods, site prepared with conventional mechanical equipment, planted with bareroot spruce, and treated with either motor-manual, mechanical, or chemical methods to ensure the survival and growth of the spruce. Five-year results showed that the nine-year-old mixedwood forest remained highly dynamic and resilient. For example, reductions in the abundance of the woody shrub layers were immediately (within one growing season) followed by increases in the abundance of the sedge, graminoid, and herb layers. Species richness was increased by the treatments. In this study, cutting did not eliminate resprouting of white birch, trembling aspen, or balsam poplar. Although each of the treatment combinations led to enhanced survival and growth of the conifer crop trees, none led to the development of pure, single-layered monocultures.

Because of variations in logging disturbance (timing and intensity), relationships between pre- and post-logging species composition are often obscure, especially during the first few years following canopy removal. Typically, sites where the forest floor remains virtually undisturbed following logging, support vegetation that resembles the understorey species community which existed before logging (Dyrness 1973). Often, on these sites with an undisturbed forest floor, residual species greatly increase their coverage following overstorey removal and virtually exclude invading species in the herb and shrub layers.

Species composition should be expected to have some impact on post-harvest stand development following clearcut harvesting (Yang and Fry 1981). Although the forest floor is often dramatically altered by harvesting and subsequent site preparation, seeds from competing vegetation are not removed from the site by these treatments (Moore and Wein 1977). Intense competition from competitive non-crop woody vegetation often occurs immediately after logging and originates from the sprouting of basal buds, rhizomes, and/or root suckers (Zasada *et al.* 1988). Mechanical logging and site preparation can destroy or seriously damage advance conifer growth, which may help to eliminate unwanted balsam fir (Yang and Fry 1981, Morris *et al.* 1988).

Clearcutting generally provides conditions suitable for the re-establishment of sprouting and suckering shrub species and hardwoods, although severe soil disturbance can reduce this capacity. Since suckering capacity is dependent on soil temperature, sites with heavy grass competition and thick duff layers may experience reduced re-establishment of suckering species.

MacDonald (2000) investigated the application of clearcutting versus partial cutting to maintain conifers in two boreal mixedwood conditions in northeastern Ontario. On one site, understorey hardwood densities increased from 2,800 stems per hectare in the uncut control to 28,000 stems per hectare in the clearcut blocks. Clearcut blocks on a second mixedwood study area also had higher shrub stocking than uncut plots. In contrast, the understorey density of hardwoods associated with a 50 percent level of basal area removal was intermediate to that of the control or clearcut treatments. Partially cut plots had lower stocking to woody shrubs than either of the clearcut or control blocks. On boreal mixedwood sites, preventing hardwood dominance in the post-harvest condition would appear to require vegetation control even if the stand is only partially cut.

Clearcutting followed by annual cleaning for at least three years post-disturbance maximized both the survival and growth of planted white spruce. Likewise, diameter growth of black spruce was proportional to cleaning frequency of planted northern boreal conifers (Wagner *et al.* 1996). The volume growth of conifer seedlings consistently increases after competition is controlled (Lautenschlager 1995, Wagner *et al.* 1999).

Alternative harvesting methods may help reduce the level of competition in the regeneration environment. Groot (1999) suggests that shelterwood cutting combined with subsequent vegetation control produces optimum conditions for establishing white spruce. The challenge is to enrich the conifer content enough to produce the desired mix of crop species while favouring the spruces. MacDonald (2000) determined that under-planting a 50 percent removal partially cut boreal mixedwood stand with white spruce, and applying a single cleaning after the second growing season using herbicides, resulted in sustained survival and growth of the planted white spruce.

For additional information on the responses of vegetation to silvicultural practices, refer to Section VII.

Disturbance Agents

Disease

Tree disease is damage to trees caused by pathogens such as fungi, bacteria, viruses, and parasitic plants (Manion 1991). Damage to trees includes mortality, growth reduction, deformation, predisposition to other pests or to windfall, and a general reduction in stem quality (e.g. butt rot). Several of these symptoms can be present simultaneously and usually intensify over time. However, not all disease impacts are negative. Organisms that are responsible for many native tree diseases are also integral components of balanced ecosystems contributing to processes such as nutrient cycling, forest succession, and the provision of coarse woody debris that may function as both seedbeds and habitat (Shaw and Kyle 1991, Manion 1991, Haack and Byler 1993, Harmon *et al.* 1996).

Forest management practices like harvesting, renewal, and stand tending can potentially alter the prevalence, severity, and spread of disease (McLaughlin 2001). Although diseases are common and require consideration in the management of all sites, boreal mixedwood sites present some unique management opportunities and challenges. For example, boreal mixedwood sites do not include particularly dry or wet sites, which may impact on the viability and virulence of certain pathogens (e.g. Shaw and Kyle 1991, Whitney 1995). Likewise, the use of various partial canopy removal methods may require special attention to avoid unforeseen pathological impacts (McLaughlin 2001).

The following discussion is based on reviews by Greifenhagen (2001), McLaughlin (2001), and Whitney *et al.* (2001).

Role of Disease During Stand Development

Literally hundreds of organisms can cause disease in trees but only a few pathogens are significant at the stand level (Greifenhagen 2001). The most important root and stem diseases of the five defining boreal mixedwood tree species are listed in Table 3.

Successional trends in these commonly occurring tree diseases often follow changes in the age and composition of tree species comprising a stand (Greifenhagen 2001, McLaughlin 2001). If a stand follows the classic successional pathway on a boreal mixedwood site (i.e. from hardwood dominated through a hardwood softwood mixture to a softwood dominated condition), major diseases may occur in the following sequence.

- At the stand initiation stage, any residual inoculum in roots and stumps can be a potential source of new infection to both advance growth and new regeneration for many years.
    - Aspen suckers or conifer seedlings in contact with stumps or dead roots colonized by *Armillaria* may become infected (Stanoz and Patton 1987). Balsam fir is the most susceptible of the conifers, followed by black spruce, then white spruce (Whitney 1989, 1995). If the buildup of *Armillaria* is large enough, regeneration success can be negatively impacted and cause openings in the regenerating stand.
    - Where *Venturia macularis* causes aspen leaf and shoot blight, aspen stands can experience up to 100 percent infection (Gross and Basham 1981). Stems damaged by this disease tend to become susceptible to infection by other decay agents. Leaf and shoot blight rarely affects aspen taller than seven metres (Gross and Basham 1981).
- As a stand develops into the stem exclusion stage, the incidence of stem decay increases (Basham 1991).
    - Hypoxylon canker (*Entoleuca mammata*) is the disease most damaging to aspen at this stage. Mortality is greatest in young saplings and small trees when cankers develop on the main stem (Perala 1984). Fully stocked aspen stands may have lower rates of Hypoxylon infection than poorly stocked stands (e.g. Anderson 1964, Anderson and Anderson 1968, Lux 1998), although this is not always the case (Pitt *et al.* 2001).
    - In lower density stands, aspen tends to exhibit increased branchiness. The resulting branch stubs provide possible entry points for decay fungi, such as stringy white rot (*Phellinus tremulae*), that primarily enter through branch stubs 1.5 centimetres or more in diameter (Basham 1993).
- By the canopy transition stage, diseases associated with conifers and aging hardwood trees become more prevalent.
    - Aspen tends to be the most susceptible to stem decay at this stage, the most destructive pathogen being stringy white rot (which is rare in aspen younger than 40 years of age) (Basham 1993).
    - The incidence of Hypoxylon canker increases in aspen, but most of these cankers are located on branches within the crown and do not cause tree mortality (Falk *et al.* 1989).
    - Tomentosus root rot can spread to infect black and white spruce through direct root contact

Table 3. Important diseases affecting the five defining boreal mixedwood tree species.

Disease	Aspen	White birch	Black spruce	White spruce	Balsam fir
Root disease					
Armillaria spp.	●	●	●	●	●
Inonotus tomentosus (Tomentosus root rot)[a]			●	●	○
Stem disease					
Phellinus tremulae	●				
Phellinus pini			●	●	●
Stereum sanguinolentum					●
Entoleuca mammata (Hypoxylon canker)	●	○			
Venturia macularis (aspen leaf and shoot blight)	●				

(● = common host, ○ = occasional host).

[a] Most prevalent on poor dry sites but can also occur on boreal mixedwood sites.
Source: Adapted from Greifenhagen (2001).

  (Whitney 2000). In mixed aspen-spruce stands where direct contact between spruce roots occurs less frequently, the spread of this disease may be restricted because aspen is virtually resistant to Tomentosus (Whitney 2000).

  - Stands with a high component of balsam fir may be greatly affected by *Armillaria* root disease, causing tree death and windfall to occur before 70 years of age.
  - Mixed hardwood-conifer stands may be associated with higher incidences of decay in balsam fir from *Stereum sanguinolentum* (Heimburger and McCallum 1940).

- At the gap dynamics stage, diseases often play a large role in tree mortality and the creation of canopy gaps. Stem decay in living trees typically increases as trees age and overmature trees almost always contain some decay (Basham 1991). Entry points for disease increase as trees age and lose their vigour, thereby increasing the extent of internal decay.
  - Late successional stands are typically characterized by a high component of balsam fir. These stands tend to be more susceptible to *Armillaria* root disease, particularly during insect outbreaks of eastern spruce budworm (Greifenhagen 2001, McLaughlin 2001). In mixedwood stands, balsam fir killed by spruce budworm may act as reservoirs for root disease, thereby increasing the risk of losing spruce.

Management Opportunities and Challenges

There are three general areas of disease management to consider when managing boreal mixedwood sites:

- pre-existing levels of disease
- effects of harvesting practices on disease
- effects of post-harvest practices on disease

Pre-existing Levels of Disease

Pre-existing levels of disease, as indicated by signs of root disease, tip blights, cankers, or excessive decay, can suggest future disease problems. *Armillaria* inoculum left behind in infected stumps and root systems can remain a source of inoculum for many years. In addition, stumps and root systems of other harvested or killed trees may be sources of new and higher levels of infection for many years. Where known sources of inoculum are present, less susceptible tree species could be regenerated, or steps could be taken to eliminate or reduce the inoculum (McLaughlin 2001).

Effects of Harvest Practices on Disease

Where partial canopy removal methods are used, resource managers need to be aware of any associated pathological legacy (McLaughlin and Dumas 1996)[1]. Trees already infected with stem decay fungi are poor candidates for residual trees (McLaughlin 2001). White and black spruce have shallow rooting habits and will be particularly vulnerable to windthrow if their root systems are damaged by root rots (Whitney 1989). These potential losses must be taken into account (McLaughlin and Dumas 1996).

Whenever a stand is harvested, it is inevitable that some residual trees will be injured by machinery, providing additional entry points for wood decay fungi (Whitney 1979, 1991). Therefore, care should be taken to minimize the wounding of residual trees during harvesting operations (Rice 1994).

Effects of Post-harvest Practices on Disease

Post-harvest practices such as site preparation, regeneration methods, and stand tending may influence disease patterns on any given site. For example:

- Site preparation can damage aspen suckers resulting in high levels of *Armillaria* and infection by a number of stem decay fungi, which can negatively impact the wood quality of surviving trees (Basham and Navratil 1975, Basham 1982b, 1988).
- In contrast, aspen suckers that survive herbicide treatment appear to have the same potential to develop into good quality crop trees as untreated individuals (Basham 1982a).
- The accumulation of *Armillaria* in the roots of herbicide-killed hardwoods may spread to released coniferous crop trees.
- The spread of root disease may be reduced if highly susceptible tree species are distributed among resistant or less susceptible tree species, forming a barrier to the spread of pathogens.
- Thinning aspen may increase infection by Hypoxylon canker and subsequent mortality (Anderson 1964, Anderson and Anderson 1968, Lux 1998) but this is not always the case (Pitt *et al.* 2001).

More specific steps to reduce losses from tree disease are given in McLaughlin (2001).

Insects

Insect activity that has a negative impact on harvestable wood fibre, is described as "insect damage". Numerous insects cause damage and mortality to trees on a localized basis, but under certain circumstances some insects also cause damage over large areas. Although several insect defoliators are important to boreal mixedwood forests, only a few have substantial impact on successional pathways. For example, while large aspen tortrix (*Choristoneura conflictana*) and birch skeletonizer (*Bucculatrix canadensisella*) are found frequently at outbreak levels, the impact is low because these insects tend to cause defoliation for only one to three years, which results in very little tree mortality (Prentice 1955, Howse 1981, 1995). In contrast, eastern spruce budworm routinely causes mortality to balsam fir over large areas (Blais 1985, Howse 1995).

While insect outbreaks can be considered a problem because of the economic importance of lost timber, these disturbances are an integral part of terrestrial ecosystems. Insects provide links within community food webs, contribute extensively to carbon and nutrient cycling, direct forest succession, and provide coarse woody debris as seedbeds and habitat (Schowater *et al.* 1986, Attiwill 1994, Haack and Byler 1993).

The discussion below is based on reviews by Howse (1995), Fleming *et al.* (2000), Scarr *et al.* (2001), and Kayahara (in prep. a).

Role of Insects During Stand Development

Trends in insect damage during stand development largely follow changes in tree species composition.

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[1] Clearcutting also leaves behind potential inoculum in stumps and dead roots. However, for partial canopy removal methods the legacy of retention is more visible, and prescriptions such as aggressive site preparation and stump pulling would not generally be used.

Stand Initiation Stage

Although numerous insect species feed on regenerating tree shoots and foliage, only a few insects regularly have a significant effect on tree establishment at the stand initiation stage in Ontario's boreal forest:

- Spruce budworm and forest tent caterpillar can sometimes be serious pests of spruce and aspen, respectively; however, budworm rarely causes mortality until stands are greater than 20 to 25 years of age (MacLean 1980, Scarr *et al.* 2001).
- If white spruce stands were to become common on the landscape (e.g. as a result of planting efforts), three endemic insect species that might also become a concern are yellowheaded spruce sawfly (*Pikonema alaskensis*), spruce budmoth (*Zeiraphera canadensis*), and white pine weevil (*Pissodes strobi*).
    - The yellowheaded sawfly can be an important defoliator of white spruce under exposed conditions at the stand initiation stage. Three to four years of moderate defoliation usually kills the tree (de Groot 1995, Howse 1995, Scarr *et al.* 2001).
    - The spruce budmoth feeds primarily on white spruce shoots; white spruce is susceptible to the moth from a height of about one metre until crown closure (Carrow 1985, Turgeon *et al.* 1995, Scarr *et al.* 2001).
    - White pine weevil may attack the leaders of white spruce when it is growing under exposed conditions characteristic of the stand initiation stage (Humble *et al.* 1994).
    - Although spruce budmoth and white pine weevil can deform and possibly stunt open-grown spruce, the trees are generally not killed.

Stem Exclusion and Canopy Transition Stages

During the stem exclusion and canopy transition stages, both forest tent caterpillar and spruce budworm can have major impacts on the successional pathway of a stand, although other insects may also be important:

- Forest tent caterpillar
    - Forest tent caterpillar outbreaks begin approximately every 10 years (outbreak return intervals range from six to 16 years) (Hidalh and Reeks 1960, Sippel 1962) and usually last three to four years (Witter 1979). Normally, only localized mortality occurs during an outbreak (Churchill *et al.* 1964, Witter *et al.* 1975).
    - Recently, repeated and prolonged defoliation of aspen by forest tent caterpillar in northeastern Ontario has been accompanied by aspen mortality (Keizer and Melbourne 2002). It is estimated that over 300,000 hectares of aspen dominated and aspen leading stands have experienced up to eight years of repeated defoliation, resulting in aspen mortality or decline (Keizer and Melbourne 2002).
    - Depending on understorey composition, subsequent succession in these stands appears to be tending towards a balsam fir dominated or brush-field condition (Brian Fox, pers. comm.).
    - Although white birch may also be defoliated by forest tent caterpillar later in the season, widespread mortality of birch has not been associated with the recent decline in aspen.
- Spruce budworm
    - Outbreaks of spruce budworm, usually lasting from five to 15 years, have caused tree mortality over large areas in Ontario at 30-year intervals on average. Budworm-free periods are variable, lasting 20 to 60 years (Blais 1985, Fleming *et al.* 2000).
    - The primary hosts of spruce budworm are balsam fir, white spruce, and black spruce; vulnerability to the insect generally decreases in the same order. Balsam fir commonly experiences mortality after four to five successive years of complete defoliation, while white spruce may die after six to eight years. Black spruce response is more variable (Howse 1981, Blais 1985, Scarr *et al.* 2001).
    - Where balsam fir forms a major portion of the canopy and subcanopy and is killed during a budworm outbreak, stand development may be delayed, i.e. returned to a younger balsam fir stand or setback to a condition with a larger component of aspen or birch (Ghent 1958,

Morin 1994, Osawa 1994, Paré and Bergeron 1995, Kneeshaw and Bergeron 1999).

  - Generally the vulnerability of balsam fir to budworm decreases as the proportion of hardwoods in a stand increases (MacLean 1980, Su *et al.* 1996, Needham *et al.* 1999).
  - Regardless of the amount of damage to overstorey balsam fir, understorey balsam fir appears to be somewhat protected from budworm. Budworm females have difficulty finding and colonizing understorey trees.
- Poplar borer (*Saperda calcarata*) and bronze birch borer (*Agrilus anxius*)
  - As aspen trees become weakened, either by successive forest tent caterpillar defoliation or simply by old age, infestation by poplar borer tends to increase (Peterson 1947, Graham and Mason 1958). Tunnels created by this insect serve as infection courts for wood-rotting fungi (Graham and Harrison 1954, Anderson and Martin 1981), and structurally weaken trees, increasing their susceptibility to wind damage (Drouin and Wong 1975).
  - Trees are most susceptible to the poplar borer during the later part of the canopy transition stage, as borer infestations tend to increase with host tree diameter and decrease with density.
  - The bronze birch borer has also been noted to attack weakened aspen and birch trees. Whether it is insect defoliation or drought conditions that actually attracts this borer has yet to be established (Balch and Prebble 1940, Anderson 1944).

Gap Dynamics Stage

At the gap dynamics stage, the hardwood component is generally small or absent, and there is a natural tendency for balsam fir to comprise a larger component of the stand. Spruce budworm can have diverse effects on the successional pathway:

- The immediate effect of a spruce budworm outbreak is to reduce the proportion of balsam fir in the upper canopy. However, understorey balsam fir may survive, thereby allowing for eventual perpetuation of the fir component (Fye and Thomas 1963, Scarr *et al.* 2001).
- White and black spruce are less vulnerable than balsam fir to budworm-induced mortality. However, spruce budworm can attack the flowers of these species thereby reducing the number of cones and viable seeds produced (Blais 1985, Fogal and Larocque 1992). Where white spruce is unable to reproduce (from lack of seed production and/or suitable seedbeds), the resulting stand composition may be one with reduced balsam fir, relic white spruce, and a largely unchanged component of black spruce (Gordon 1985, Nealis and Ortiz 1996, Scarr *et al.* 2001).
- Following widespread spruce budworm damage, the potential for summer fires may peak five to eight years following stand mortality (Stocks 1985, 1987). If a fire subsequently occurs, the stand could be setback to the stand initiation stage.

Management Opportunities and Challenges

It seems that nothing can be done to prevent or control regional insect outbreaks because management actions are usually directed at individual stands. While the spraying of insecticide can prevent defoliation and allow trees to recover, it does not stop the outbreak from moving across the landscape (Baskerville 1975).

Stands of maturing balsam fir may currently be overrepresented on the landscape, due primarily to past silvicultural practices and fire suppression (Blais 1983). Once a landscape has developed substantial proportions of maturing balsam fir, budworm populations appear to increase, forming epicentres from which successive bands of infestation may extend outwards (Royama 1984). Any action directed at reducing the preponderance of balsam fir epicenters may help reduce the number and duration of recurring outbreaks. Suitable boreal mixedwood management practices might include (Mattson *et al.* 1988, Blun and MacLean 1985):

- Reducing the proportion of mature balsam fir dominated stands across the landscape.
- Aiming to regenerate spruces rather than fir (balsam fir will fill in naturally).

- Avoiding the use of natural seeding of spruce using the seed tree or shelterwood methods during outbreaks of spruce budworm (budworm feeding has a severe impact on flowering in spruces).
- Maintaining mixed stands of hardwoods and softwoods on boreal mixedwood sites.
- Using a range of silvicultural practices to create a diversity of ecosystems at the stand and landscape level.

Herbivory

Herbivory refers to the consumption of plant material such as leaves, twigs, bark, and seeds by mammals (e.g. moose [*Alces alces*], white-tailed deer [*Odocoileus virginianus*], snowhoe hare [*Lepus americanus*]). Currently, herbivory is not considered a significant problem in Ontario's boreal forest (McNicol 2001). However, research done in boreal forests outside of Ontario suggests that there is some potential for herbivory to become a problem where partial canopy removal methods are used in forest management.

The following discussion is based on a review by Taylor and Vasiliauskas (in prep.).

Role of Herbivory During Stand Development

The impact that herbivory can have on boreal mixedwoods varies with stand development stage (Newton *et al.* 1989, Ford *et al.* 1993, Reimoser and Gossow 1996), largely because of differences in tree size (susceptibility of trees to browse) as follows:

- Seedlings are more susceptible to herbivore damage than saplings and larger trees due to their smaller size. It is possible for a herbivore to consume an entire tree (seedling) at the stand initiation stage.
- At later stages of stand development, herbivores tend to damage larger trees without directly causing mortality (McNicol 2001). Indirectly, by stripping bark or by breaking branches, a herbivore may provide entry routes for pathogens.

Dietary choices of herbivores can influence species composition, particularly at the stand initiation stage:

- By selectively eating conifers (Telfer 1972, Joyal 1976, Rodger and Sinclair 1997, Timmermann 1998), herbivores may move a stand towards a more hardwood species composition.
- By selectively eating hardwood trees, herbivores may move a stand towards a more coniferous composition.
- Herbivores can also facilitate overall stand growth by consuming understorey competition.

Generally, herbivory is not uniform within a stand (Adler *et al.* 2001). Rather, it tends to be patchy because certain plant species are more desirable as forage than others (Senft *et al.* 1987), and forage species are patchy in their distribution. These patterns may combine to either increase or decrease the heterogeneity of vegetation (Adler *et al.* 2001). A few studies indicated that herbivory increased the heterogeneity of vegetation within a stand (Adler *et al.* 2001).

Management Opportunities and Challenges

Where problems with herbivory occur, large-scale landscape and demographic patterns are often the cause (Senft *et al.* 1987):

- Silvicultural practices at a landscape level may have combined to provide herbivores with optimal habitat conditions (food, thermal cover, hiding places, water, birthing areas, and lack of predators) that allow their populations to radically increase.
- Many herbivores have distinct natural population cycles that operate irrespective of management practices (Banfield 1977). Attempting to regenerate a stand when a known herbivore, like snowshoe hare, is at the peak of its cycle, may be challenging. Understanding natural herbivore population cycles and avoiding cyclic peaks may greatly increase management success.

At the stand level, research outside of Ontario's boreal forest shows an increased impact of herbivory on forest regeneration with the use of shelterwoods and other partial canopy removal methods. Partial canopy removal methods may provide a combination of shelter and forage quantity and quality that may be preferred by herbivores relative to both uncut and clearcut stands. For example:

- In a comparison of silvicultural systems in Sweden (Nystrand and Granstrom 2000), herbivory was found to be highest in newly cut shelterwood stands, intermediate in unlogged stands, and lowest in new clearcuts. The explanation for this pattern was that shelterwoods provided cover while opening the canopy also increased the amount of available light and promoted shrub and sapling growth.
- In a comparison of thinned and unthinned balsam fir stands in Newfoundland (Thompson *et al.* 1989), moose preferred to browse in the thinned stands where balsam fir twigs had higher protein levels. The browse from thinned stands also had lower levels of secondary metabolites, considered to be a plant defence against browsing.

With the exception of balsam fir, defining boreal mixedwood conifers are not preferred browse species for ungulates[3]. Consequently, whether ungulate herbivory becomes an issue under partial canopy removal scenarios in Ontario, will depend on the need to protect balsam fir.

If herbivory becomes an important issue for boreal mixedwood management, research will be needed specific to Ontario's situation. If factors that create herbivory problems occur at the landscape level rather than at the individual stand level, landscape management impacts will need to be investigated.

Decisions about wildlife management in boreal mixedwoods need to be made in a way that balances the intrinsic value of wildlife with any impact they may have on tree regeneration.

For information on possible mitigating measures that can be used with specific mammalian herbivores, refer to Taylor and Vasiliauskas (in prep.).

Wind Damage

Wind causes disturbance in boreal forests at various scales and may influence natural succession. Wind damage depends on the interaction of storm characteristics (season, wind direction, average and maximum wind speed) with site conditions, and internal stand characteristics (Stathers *et al.* 1994, Mitchell 1995, Navratil 1995, Ruel 1995). Windthrow risk can vary at different stand development stages and can be influenced by management interventions. Understanding the influence of windthrow on stand development and how silvicultural treatments can influence windthrow risk is important for successful boreal mixedwood management.

Role of Wind Damage During Stand Development

Wind damage includes both tree uprooting and stem snapping. It has a direct effect on individual tree mortality and may influence stand development by affecting tree recruitment and site productivity. Uprooting affects forest ecosystems by creating canopy gaps, exposing mineral soil (a good seedbed for most species), increasing nutrient availability through mixing of organic and mineral layers, and providing coarse woody debris (downed logs and branches) that, once sufficiently decayed, may act as suitable substrate for seedling establishment by some species (Stephens 1956, Beatty and Stone 1986, Schaetzl *et al.* 1990, Bormann *et al.* 1995). Stem snapping can influence tree recruitment by promoting root suckering in aspen, stump sprouting in birch, and by contributing coarse woody debris as potential seedbeds.

At any stage of stand development, the likelihood of both large- and small-scale windthrow events occurring is dependent on the susceptibility of individual trees to windthrow, which is a function of:

- Site conditions (soil moisture and depth, and topography).
  - Windthrow risk is usually higher on moist and wet sites (Navratil 1996). Many tree species

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[3] Deer only consume balsam fir under starvation conditions.

exhibit shallower rooting habits in wetter soils than in drier soils (Navratil 1995).

  - Wind speed, and therefore the risk of wind damage, varies with topographic features (Navratil 1995). For example, in boreal forests mean annual wind speed can be twice as high on hilltops than in valleys (Ruel *et al.* 1997, 1998).

- Tree and stand characteristics (tree height, stem taper, root development, age and condition, species, stand density, and edge effects).
  - Risk of wind damage generally increases with tree height (Veblen *et al.* 2001); vulnerability increases greatly above 10 metres (Busby 1965).
  - Risk of wind damage increases with stem taper, which is influenced primarily by density.
    - The slenderness coefficient, expressed as a height per dbh ratio, characterizes stem taper and serves as an index of tree stability (Navratil 1995). A tree with a slenderness coefficient greater than 100 is considered to be at high risk for windthrow (Navratil 1996), although species with similar slenderness coefficients may be more or less susceptible than other species because of factors like rooting habit. Slenderness coefficient data for Ontario suggest that boreal mixedwood species are often at risk for windthrow, especially in subordinate canopy positions (Table 4).
  - Risk of wind damage is influenced by the degree of root development; it varies with species and is a function of site quality and shading (Navratil 1995). Trees with poorly developed root systems (e.g. understorey trees not preconditioned to exposed conditions) are at a high risk for windthrow.
  - Risk of wind damage increases with age and condition (increasing tree height), canopy gaps (increased wind exposure), and development of decay (e.g. balsam fir tends to exhibit lower windfirmness due to a high incidence of decay by age 50) (McClintock 1954, Basham 1992). Standing dead trees of all species are more easily snapped than windthrown since their stems are weakened and decayed (Veblen *et al.* 2001) and they lack a crown to act as a "sail" that catches the wind.
  - Risk of wind damage varies with species, largely as a function of rooting habit, branch flexibility, crown permeability to wind (Navratil 1995), and resistance to decay. In general, hardwoods are less susceptible to windthrow than conifers (Savill 1983, Everham and Brokaw 1996, Ruel and Benoit 1999, Ruel 2000). Of the conifers, balsam fir may be particularly susceptible to stem breakage because of a characteristically high rate of decay at an early age (McClintock 1954, Basham 1992). Black and white spruce are less susceptible because butt and root rots develop at a later age in these species (Ruel and Benoit 1999).
  - Risk of wind damage varies with stand density (Navratil 1995). Very dense, homogeneous stands usually exhibit a low level of damage. Wind penetration into these stands is low and support from neighbours is maximized. Low-density stands can also suffer minimal damage when trees are windfirm as a result of preconditioning.
  - Risk of wind damage increases when stand edges are suddenly exposed to increased wind penetration into the stand (Navratil 1995).

Where wind damage occurs, two scales of damage can be distinguished: catastrophic wind damage (large-scale disturbances) and single- or multiple-tree windfalls (small- to medium-scale disturbances). These two types of wind damage can result in different successional pathways.

Catastrophic (Large-scale) Windthrow

In northern Ontario's boreal forest, catastrophic windthrow caused by severe windstorms occurs periodically when strong winds develop along cold fronts (Gardiner 1975). Catastrophic wind damage can cause total destruction of the tree canopy, although a significant amount of biological legacy usually remains (Nowacki and Kramer 1998).

Catastrophic windthrow can cause wind damage at all stages of stand development. Stand-replacing catastrophic windthrow at the stand initiation stage and early in the stem exclusion stage can reverse

Table 4. Average slenderness coefficients (height/diameter ratio) of the five defining boreal mixedwood species in the canopy and the subcanopy at three stand development stages on boreal mixedwood sites.

	Canopy Trees			Subcanopy Trees		
Species	Stem Exclusion	Canopy Transition	Gap Dynamics	Stem Exclusion	Canopy Transition	Gap Dynamics
Trembling aspen	87	89	97	115	124	116
White birch	88	86	69	115	129	132
Black spruce	90	81	82	101	97	91
White spruce	not available	65	69	80	82	98
Balsam fir	not available	76	85	89	91	98

Shading denotes a relatively high average risk of windthrow and/or snow damage (defined as slenderness coefficient > 100). Source: Popadiouk *et al.*, in prep.

classical succession if conifer advance growth is not present or is unable to survive. This process has been observed in conifer dominated boreal forests in Russia and Japan (Turkov 1979, Ishizuka *et al.* 1998). Conversely, succession can be accelerated if advance growth is abundant and survives to form the new stand or if a conifer understorey that has not yet penetrated into the main canopy sustains only minimal damage from a severe windstorm (e.g. as in Minnesota jack pine and aspen-birch forests; P.J. Anderson *et al.* 2001). However, the successional pathway can be affected when advance growth development is delayed by aggressive understorey vegetation (Arévalo *et al.* 2000).

A cyclical successional pathway can also occur following catastrophic windthrow when current species composition is maintained. This latter process has occurred in mature balsam fir stands in Quebec where severe spruce budworm epidemics contribute to subsequent blowdown. New balsam fir stands are formed by advance growth that survive the disturbance (Morin 1994, Kneeshaw and Bergeron 1998).

Single- or Multiple-tree (Small- to Medium-scale) Windthrow

Small- to medium-scale wind disturbances, such as single- or multiple-tree windthrow, play an important role in boreal forests that have developed over long periods of time in the absence of stand-replacing disturbances. Windthrow at this scale leads to gap phase dynamics due to the formation of canopy gaps (Chen and Popadiouk 2002). The successional pathway following gap formation is determined by subsequent regeneration. Typically, changes in vegetation structure occur only if a windthrow gap is larger than the surrounding canopy height (Collins *et al.* 1985).

Single- or multiple-tree windthrow is infrequent at the stand initiation stage and early stem exclusion stages, because of the short and/or closed canopy. Individual or multiple-tree windthrow begins later during the stem exclusion stage, as trees become more vulnerable because of their increased height. Rotting logs produced from windthrown trees may become available as seedbeds in the late stem exclusion stage.

By the canopy transition stage, windthrow risk may increase due to an increased conifer component in the main canopy (conifers are at greater risk for windthrow than hardwoods) and the occurrence of decay in both conifers and hardwoods. Windthrow will be more prevalent and gaps may expand faster on more productive boreal mixedwood sites, providing a rapid increase of light and nutrient resources to understorey vegetation. On dry and fresh loam, and sandy loam sites, conifer roots are much deeper and, therefore, the risk of windthrow is less. As a result, trees may break rather than be uprooted (MacLean 1960).

At the gap dynamics stage, canopy gaps due to windthrow of individual stems or groups of trees occur frequently because of the high incidence of rotten boles (Fleming *et al.* 2000). Frequently, windthrow of large trees creates a massive input of coarse woody debris that, when sufficiently decayed, provides numerous microsites favourable for conifer regeneration (Harmon *et al.* 1986, Paré and Bergeron 1996).

Management Opportunities and Challenges

Even-aged silvicultural systems or harvest methods that remove most of the canopy in a single operation can emulate, to some extent, the scale of canopy openings caused by catastrophic windthrow (Nowacki and Kramer 1998). Some biological legacies and coarse woody debris must be retained with these methods (OMNR 2001b). Topographic locations that are susceptible to recurrent stand-replacing wind events are most suited to even-aged silvicultural systems. Uneven-aged silvicultural systems that use individual or small group removals are most suited to wind-protected sites where small-scale windthrow leads to gap phase replacement.

Unacceptable levels of windthrow can potentially result from two-stage harvesting and partial canopy removal methods. Two-stage harvesting puts the released and previously unexposed (i.e. unconditioned) understorey at risk of windthrow. Residual canopy trees retained in partial canopy removal methods are at risk from increased wind penetration into the stand. Consequently, sites that are exposed to frequent, high-speed winds are not prime candidates for these silvicultural approaches.

The following procedures can be used to assess and/or minimize wind damage risk:

- Assess windiness in the region, including predominant wind direction and frequency of high-speed wind events (Navratil 1995).
- Develop windthrow risk models to produce landscape level maps of windthrow hazard and evaluate the relative risk of various cutblock designs (Mitchell *et al.* 2001).
- Use cutblock designs that reduce wind damage risk.
    - Integrate windbreaks with clumps or strips of conifers and hardwoods (Navratil 1995).
    - Use feathered or serrated cutblock edges to reduce the risk of wind damage (Gilles 1997).
- Orient skid trails perpendicular to the prevailing direction of strong winds (Navratil 1995).
- Use site preparation methods that minimize windthrow risk (plowing can reduce lateral root spread and is not advised) (Navratil *et al.* 1994).

  Note: consider the effect that tree uprooting has on the maintenance of forest productivity through soil mixing when choosing site preparation treatments
- Implement a density management strategy to promote wind resistance (Navratil 1995).
    - Maintain a high-density, homogeneous, uneven-aged stand.
    - Use initial spacing and thinning regimes to promote well-crowned, well-rooted trees with desirable slenderness coefficients.
- Evaluate understorey stand structure before implementing two-stage harvesting (Navratil 1995).
    - Determine the slenderness coefficient for understorey trees to be released.
    - Evaluate understorey height structure and spatial distribution.
- Where two-stage harvesting is considered appropriate (Navratil 1995):
    - Remove tall (> 10 metres), slender trees (slenderness coefficient 100).
    - Leave larger well-spaced, windfirm trees.

  - Apply density management to understorey trees to improve growth, yield, and stability.
  - Leave some understorey trees in clumps for mutual support.
- Where most understorey trees have slenderness coefficients greater than or equal to 100, use a shelterwood system or strip cut:
  - Consider strip widths less than three canopy heights and orient strips perpendicular to the prevailing winds (Flesch and Wilson 1998, 1999a, b, c)
  - Remove 50 percent of overstorey basal area in the first pass to increase light and wind stimulus, thereby improving the stability of released trees (Navratil 1995).
  - Allow at least five years between harvest passes to improve the stability of released trees (Navratil 1995).
- For any partial canopy removal method (in addition to previous recommendations where applicable):
  - Select residual trees that are windfirm (dominants with slenderness coefficient < 100 and small-crowned trees < 10 metres tall) (MacDonald 2000).
  - Consider harvest intensities of up to 50 percent basal area on susceptible sites and no more than 35 percent in older stands (MacDonald 2000, Ruel *et al.* 2000b).
  - Consider group patterns of retention instead of dispersed patterns of retention, and teardrop-shaped patches instead of linear-shaped patches (Franklin *et al.* 1997). Dispersed patterns involve retaining trees in an even distribution throughout the stand; group patterns involve retaining trees in patches throughout the stand.
  - Consider branch/top pruning of 20 to 30 percent of the crown of selected residuals to reduce the wind-capturing surface (sail area) (Stathers *et al.* 1994).
    - Response may vary with species (Gilles 2001); no studies have been implemented with boreal mixedwood species.
  - When mechanically scarifying among residuals, avoid root damage that could reduce the physical strength of the tree and allow entry to pathogens (Navratil *et al.* 1994).

Snow Damage

Snow plays a significant role in stand development in the boreal forest (Gill 1974, Nykänen *et al.* 1997). Snow damage also includes loading from "glaze" (freezing precipitation that builds up and causes ice damage). For successful boreal mixedwood management, it can be important to understand how snow damage varies at different stages of stand development and how silvicultural interventions at these stages can influence the risk of snow damage.

Role of Snow and Ice Damage During Stand Development

Snow damage is caused by a buildup of large accumulations of snow or ice on tree crowns and stems. Crown or stem breakage, stem bending, or uprooting occurs when a particular component of a tree fails to resist heavy snow loading. Stem breakage is the most common type of snow damage, especially in mid-successional or mature stands (Gill 1974, Petty and Worrell 1981, Peltola *et al.* 1997). Bending and uprooting can also occur (Nykänen *et al.* 1997). Uprooting can occur if the soil is not frozen (Päätalo *et al.* 1999, Peltola *et al.* 1999).

Whether or not snow damage occurs at any given stage of stand development depends on the type and quantity of snow received and the susceptibility of trees to snow damage (a function of tree and stand characteristics). The factors that affect snow damage include:

Snow Type

- Temperature affects the water content of snow and, therefore, affects its weight and ability to cling to tree crowns (Solantie and Ahti 1980, Petty and Worrel 1981, Solantie 1994).
- Snow damage is most likely to occur in late autumn

and early spring when the probability of wet snowfall is highest (Norokorpi 1981, 1994, as cited in Nykänen *et al.* 1997).

- Widespread snow damage can also occur in early autumn when warm temperatures lead to high water content and adhesion of snow (Gill 1974). Early autumn snowfalls of this type can have a greater negative impact on hardwoods because the crown surface area of aspen and birch is much greater before leaf-fall than later in the year during the normal time of snowfall.
- Ice damage from glazing typically occurs in advance of a winter warm front (Lemon 1961, Yip 1995). High winds and persistent subfreezing temperatures after an ice storm greatly increase the risk of ice damage.

Quantity of Snow Received

- Snowfalls of 20 to 40 centimetres or more at temperatures of about 0° C produce low-to-moderate risk conditions. Snowfalls of about 60 centimetres highly increase the risk of damage from heavy snow accumulation in tree crowns (Solantie and Ahti 1980, Petty and Worrel 1981, Solantie 1994).
- Low wind speeds favour large snow accumulations, particularly when snow is wet (Gill 1974). If wind speed exceeds 32 kilometres per hour, snow can be dislodged and the risk of snow loading is reduced (Solantie 1994).

Tree Size

- The risk of snow damage tends to increase with tree height (Peltola *et al.* 1997, Päätalo *et al.* 1999), although tree diameter is also a factor.
- Slender trees, 10 to 20 metres in height, are particularly susceptible to snow damage (Rottmann 1985 as cited in Nykänen *et al.* 1997).
- Small diameter trees are most likely to bend under heavy snow and ice (Rottmann 1985 as cited in Nykänen *et al.* 1997, Proulx and Greene 2001).
- Intermediate and large diameter trees are more likely to snap (Gill 1974, Petty and Worrell 1981, Peltola *et al.* 1997, Proulx and Greene 2001).
- Large diameter trees can lose a large percentage of their branches from ice damage (Proulx and Greene 2001).

Stem Taper and Crown Characteristics

- Stem taper and crown characteristics are the two main factors related to snow loading (Petty and Worrell 1981, Rottmann 1985 as cited in Nykänen *et al.* 1997, Valinger *et al.* 1993).
- Risk of snow damage is high for slender tree stems with low taper (Nykänen *et al.* 1997).
  - The slenderness coefficient can be used to evaluate snow damage risk for boreal mixedwood species (see Table 4). The probability of damage tends to be higher for trees with high slenderness coefficients than for trees with lower slenderness coefficients, as shown for boreal mixedwoods in Alberta (Gill 1974).
- Stand density decreases taper and reduces crown symmetry and, as a result, trees in dense stands tend to be at higher risk for snow damage (Rottmann 1985 as cited in Nykänen *et al.* 1997, Valinger *et al.* 1993). However, slender trees with little taper that are sheltered from snow and wind by other trees in dense stands are more protected from snow damage.
- Risk of snow and ice damage increases if crowns are asymmetric and branches are rigid and horizontal (Gill 1974, Nykänen *et al.* 1997). Crown asymmetry is crucial in determining the direction of snapping and bending (Bruederle and Stearns 1985, Hauer *et al.* 1994). Conifers such as black spruce that have narrow crowns and downward hanging branches are less susceptible to snow damage than species, such as aspen, that have broader crowns and rigid branches (Gill 1974, Rottmann 1985 as cited in Nykänen *et al.* 1997). Although white spruce tends to have upswept branches, its structural strength is superior to that of boreal hardwoods (Gill 1974).

Root Development

- Symmetric root development (spread and depth) increases tree stability (Petty and Worrell 1981, Rottmann 1985 as cited in Nykänen *et al.* 1997).
- Species that are characteristically shallow rooting (irrespective of environment) may be more

susceptible to uprooting from snow loading than deeper rooted species.

Stand Condition

- Stems may snap more easily if weakened by insects and disease.

Snow damage in the Canadian boreal forest is a recurring feature at a variety of scales, particularly along its southern border. It is estimated that catastrophic damage occurs once or twice every century in any given location (Gill 1974). Snow damage is expected to be less frequent at the stand initiation and early stem exclusion stages because of the shorter heights of dominant trees at these stages. Generally, snow damage at this stage depends on stand density. Dense young stands are at high risk of snow damage due to the prevalence of slender and unstable trees. Heavy snowfall that leads to drifting can cause widespread damage in these stands (Petty and Worrell 1981).

Snow damage has also been observed to destroy small, scattered patches of forest in older boreal mixedwood stands (Gill 1974). Snow damage of this nature generally leads to gap phase replacement. When this disturbance pattern occurs in late successional softwood dominated stands, pioneer hardwood species may invade the newly created openings, resulting in a mosaic pattern of early and late successional species that increases species diversity. Wildlife habitat tends to improve when there is an increase in edge. Snow damage can also substantially increase the coarse woody debris on the forest floor from broken treetops and branches. A further potential consequence is that the risk of attack by insects and disease may rise, because an increase in downed coarse woody debris provides more breeding material for certain pests (Schroeder and Eidmann 1993).

Although there is no documentation of the impact of ice damage on succession in the boreal forest, ice damage has been observed to have a significant impact on the dynamics of other forest types (Proulx and Greene 2001). Ice damage can either accelerate or retard stand development. This depends on the spatial heterogeneity of landscape features, including aspect and elevation, that can in turn influence intensity. Variation in disturbance intensity may contribute to maintaining forest diversity.

Management Opportunities and Challenges

Silvicultural practices that remove small, scattered patches of trees in mature boreal mixedwood stands will most closely emulate the disturbance pattern created by snow damage. These systems include group shelterwood and group selection methods.

The potential also exists to use specific silvicultural interventions to reduce the risk of snow damage at different stand development stages. For example, compositional or liberation treatments and pre-commercial and commercial thinnings may be particularly effective at reducing the risk of snow damage because stand density affects stem taper and crown characteristics. Dense stands in high-risk areas tend to be the most susceptible to snow damage because these trees have relatively little taper and shorter, asymmetric crowns. Although wide initial spacing usually increases tree stability by promoting more symmetric root, stem, and crown development, wind damage risk must also be considered. Wide spacing can result in uneven wind loading and, on sites susceptible to wind, the combined effect of snow and wind can increase snow damage. Alternatively, increased wind loading can be beneficial, removing snow from tree branches.

To reduce the risk of snow damage, the following silvicultural interventions can be applied at different stand development stages:

- Stand Initiation (and Early Stem Exclusion)
  - Leaving some larger trees at harvest to provide shelter from snow loading (Nykänen *et al.* 1997) can reduce snow damage to young stands.
  - Tree stability can be promoted by planting seedlings at stand initiation to ensure uniform spread and depth of root systems.
  - An initial planting density should be selected to promote the development of stands resistant to snow damage because taper is reduced at higher stem densities (Persson 1972).
  - Juvenile spacing or pre-commercial thinning is an option when trees are between two to three

metres and 10 metres in height (Nykänen *et al.* 1997)[6]. This will promote symmetric crown development, increased stem taper, and good root anchorage before stems reach a critical height susceptible to snow loading. The risk of snow damage may first increase for three to five years after spacing or thinning because of increased wind loading to unconditioned trees in sparser stands (Valinger *et al.* 1994).

- Stem Exclusion
  - An increase in stem taper (and thus stem stability) may be achieved by heavy thinning after crown closure. Trees with high slenderness coefficients and full crowns may be at higher risk for snow damage than trees without these characteristics. If thinning is delayed until tree height reaches 20 metres, the risk of snow damage will increase (Rottmann 1985 as cited in Nykänen *et al.* 1997). Heavy thinning should be avoided in high-risk areas, where large deposits of snow are expected to accumulate in tree crowns (Valinger *et al.* 1993, 1994).
  - Selectively removing trees with high slenderness coefficients can substantially reduce the risk of snow damage (Valinger *et al.* 1993). Low thinning (selective thinning from below) is suggested because it targets the removal of small, slender trees (Persson 1972, Schnekenberger *et al.* 1985). In contrast, high thinning (selective thinning from above) removes dominant trees thereby, rendering the remaining trees more susceptible to snow damage.
- Canopy Transition and Gap Dynamics
  - Pruning 20 to 30 percent of the crown to reduce crown size should also reduce the snow damage risk of mature stands in mid- to late-successional stages.

Non-stand-replacing Fire

Stand-replacing and non-stand-replacing fires form a continuum of burn types influenced by the physical environment (e.g. climate, weather patterns, topography, moisture regime), inherent fire behaviour (e.g. horizontal wind vortices) (Arseneault 2001), and the biological environment (vegetation cover). Non-stand-replacing fires are surface fires (that leave most overstorey trees alive while killing most understorey vegetation) and patchy fires (a mosaic of small burned and unburned patches). The former is also known as "cool wildfire" or "surface fire". The latter is sometimes denoted by a simple description of the percentage of the canopy that has survived a burn (Bergeron *et al.* 2002).

Together with stand-replacing fires, non-stand-replacing fires contribute to the variety of stand ages, vegetation types, and stand development stages occurring across the landscape. Knowledge of non-stand-replacing fires may be important for determining the variety of successional pathways possible on boreal mixedwood sites and can aid in developing recommendations for harvest levels and patterns.

Role of Non-stand-replacing Fire During Stand Development

Though the existence of non-stand-replacing fires is acknowledged (Brian Harvey, pers. comm., Dave Heaman, pers. comm., Doug McRae, pers. comm.), little attention has been paid to the role of partially burned areas within the fire perimeter. Nonetheless, the effects of non-stand-replacing fire on spatial patterning and stand development can be inferred, to some extent, from the limited literature base on the subject and the more general literature describing fire severity and patterns.

Where non-stand-replacing fires do occur, the species composition and stage of stand development influences the subsequent successional pathway.

- While crown fires are common in conifer stands owing to the low foliar moisture content (Rowe and Scotter 1973, Wang 2002) and canopy architecture of these species, surface fires (non-stand-replacing fires) may be more common in aspen stands (Day and Harvey 1981, Johnson 1992, Johnston 1996). This is because of the high foliar moisture content, lack of foliar resins, and crown height of this species, coupled in the spring with the typically high forest floor moisture associated with aspen stands.

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[6] Juvenile spacing was referred to as "thinning" in Nykänen *et al.* 1997

- Depending on the nature of the non-stand-replacing fire, it can:
  - Facilitate the regeneration of white and black spruce by retaining live trees as a source of shade and seed, modify the forest floor to create suitable seedbeds, and reduce understorey vegetation competition (Wang 2002). Concurrently, regeneration of balsam fir is at a disadvantage because this species is extremely susceptible to fire (easily eliminated as a source of seed) and is relatively slow growing.
  - Promote aspen suckering (Wang 2002), if there is aspen present in the stand and enough canopy trees are killed to create a sufficiently open light environment.

Stand development stage can also influence the susceptibility of a stand to fire. Flammability peaks early during stand development, declines as the canopy closes, and rises again as canopy gaps form (Alexander and Euler 1981). This pattern is due largely to the drier conditions associated with incomplete canopy cover typical of both early and late successional stands. In addition, the presence of ladder fuels that facilitate fire spread into the crown increases in later successional stages.

Management Opportunities and Challenges

In Ontario, harvesting standards and guidelines based on emulating natural disturbance patterns for stand-replacing fires (areas of complete burn and unburned areas within them) have been addressed in the NDPE guideline (OMNR 2001b). Although 90 percent of the total forested area burned is from stand-replacing fires (Johnson 1992), within these burned areas there may be substantial partially burned areas. In a single study available, that was for a burned area of the claybelt in Quebec, roughly five percent of what was considered a stand-replacing fire represented islands that escaped the burn altogether and up to 30 to 50 percent consisted of islands of partially burned areas (i.e. non-stand-replacing fire) (Bergeron *et al.* 2002). Further, unburned areas contributed to a gradient from high impact in severely burned areas to low impact in unburned areas (Bergeron *et al.* 2002). Given this potential for partially burned areas within burned areas, non-stand-replacing fires may be more frequent than figures describing the gross area burned might suggest. The longevity of surviving trees is uncertain, although there is some evidence that mortality occurs relatively soon in up to 50 percent of the standing trees within a partially burned area (Bergeron *et al.* 2002).

WILDLIFE HABITAT MATRIX

The wildlife habitat matrix presented in Table 5 is based on literature synthesized in existing habitat matrices for ecosites and standard forest units in Ontario (D'Eon and Watt 1994, Holloway *et al.* 2001). It has been modified using expert opinion to fit the stand composition types and development stages presented in this guide (Brian Naylor, pers. comm., Bob Watt, pers. comm., Gerry Racey, pers. comm.). The species listed in the matrix are those considered "Selected Wildlife Species" in boreal Ontario. The habitat needs of these species must be addressed in the forest management planning process (OMNR 1996).

Wildlife species are usually managed at the landscape level rather than at the stand level, but actions taken at the stand level have a direct impact on the amount of available habitat. The wildlife habitat matrix was created to allow the user to determine the wildlife habitat that is being created when managing for the different boreal mixedwood stand composition types and development stages.

Definitions specific to the habitat matrix are as follows:

Preferred habitat: Preferred habitat is defined as stand composition types and development stages in which the species is almost always found where the type or stage occurs within the geographic range of the species. It is assumed, but not always proven, that these composition types and development stages are the most important to reproduction (adapted from OMNR 1996).

Used habitat: Used habitat is defined as stand composition types and development stages where a species may be found at low densities most of the time, or at higher densities periodically. Depending on the species, used habitat may or may not be important to reproduction. Used habitats may contribute to the continuity of populations, preventing them from becoming isolated only in "islands" of preferred habitat (adapted from OMNR 1996).

Unused habitat: Unused habitat is defined as stand composition types and development stages in which a species will rarely be encountered and which are not used for reproduction (adapted from OMNR 1996).

Table 5. Wildlife habitat usage by stand development stage and stand composition type (● = preferred, ○ = used).

	Stand Development Stage																	
	Initiation						Early Stem Exclusion						Late Stem Exclusion and Early Canopy Transition					
Wildlife Species	Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated
Marten *Martes americana*															○	○	○	○
Moose *Alces alces* winter cover															○	○	○	○
Moose *Alces alces* winter browse	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○
Black Bear *Ursus americanus* Summer	○	○	●	●	○	○							○	○	○	○	○	○
Woodland Caribou *Rangifer tarandus*																○	○	○
Deer Mouse *Peromyscus maniculatus*	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○
Northern Flying Squirrel *Glaucomys sabrinus*													○	○	○	○	○	○
Showshoe Hare *Lepus americanus*	●	●	●	●	●	●	○	○	●	●	●	●	○	○	○	○	○	○
Lynx *Felix canadensis*	○	○	○	○	○	○	○	○	●	●	●	●	○	○	○	○	○	○

Table 5. (● = preferred, ○ = used) (cont.).

Stand Development Stage												
Late Canopy Transition						Gap Dynamics						
Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	**Comments**	**Wildlife Species**
○	○	●	○	●	●	○	●	○	●	●	Conifer cover, large cavity trees, and downed woody debris are of key importance.	Marten *Martes americana*
		○	○	●	●	○	●	●	●	●	Conifer for thermal protection and snow interception combined with an abundance of conifer and hardwood browse are important (Pt and Bw are preferred as browse).	Moose *Alces alces* winter cover
○	○	○	○	○	○	●	●	●	○	○	Prefers areas with high shrub cover.	Moose *Alces alces* winter browse
		○	○	○	○	○	●	●	●	○	Usage driven by mast availability (blueberries, raspberries, mountain ash, and beaked hazel) throughout the season. Greens such as dandelion and clover important before berries available. Large trees required for security cover for young. Cliffs, caves, windthrown trees, or other large structures near ground important for dens.	Black Bear *Ursus americanus* Summer
		○	○	○	○		○	○	○	○	Mixedwoods provide limited value, usually restricted to summer food availability, in a landscape occupied by caribou.	Woodland Caribou *Rangifer tarandus*
○	○	●	●	○	○	●	●	●	●	○	A habitat generalist. Prefers rich herbaceous ground cover, *Acer* seeds, and insects.	Deer Mouse *Peromyscus maniculatus*
●	○	●	○	●	●	○	●	●	●	●	Large Pt preferred for dens. *Mycorrhizal* fungi fruiting bodies associated with conifers are important food source.	Northern Flying Squirrel *Glaucomys sabrinus*
○	○	○	○	○	○	●	●	●	●	●	Dense conifer cover with abundant food and protection from predators is important.	Showshoe Hare *Lepus americanus*
○	○	●	○	●	○	○	●	●	●	●	Mature and overmature conifer are preferred for cover particularly for young. When foraging, habitat use is determined by location of main prey species, the snowshoe hare.	Lynx *Felix canadensis*

Table 5. (● = preferred, ○ = used) (cont.).

Wildlife Species	Stand Development Stage																	
	Initiation						Early Stem Exclusion						Late Stem Exclusion and Early Canopy Transition					
	Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated
Pileated Woodpecker *Dryocopus pileatus*																		
Great Gray Owl *Strix nebulosa*																		
Boreal Chickadee *Parus hudsonicus*											○	○				○	●	●
White Throated Sparrow *Zonotrichia albicollis*	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○
Ruffed Grouse *Bonasa umbellus*	○	○	○	○	○	○	●	●	●	●	○	○	○	○	○	○	○	○
Spruce Grouse *Dendragapus canadensis*									○	○	○	○						○
Least Flycatcher *Empidonax minimus*							○	○	○	○	○	○	●	●	●	●	○	○
Black-backed Woodpecker *Picoides arcticus*																		
Ruby-crowned Kinglet *Regulus calendula*														○	○	○	●	●
Bay-breasted Warbler *Dendroica castanea*													●	●	●	●	●	●
Blue-spotted Salamander *Ambystoma laterale*													○	○	○	○		

Table 5. (● = preferred, ○ = used) (cont.).

Stand Development Stage												
Late Canopy Transition						Gap Dynamics						
Aspen dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	Birch dominated	Aspen leading	Birch leading	Softwood leading	Softwood dominated	**Comments**	**Wildlife Species**
●	○	●	●	●	●	○	●	●	●	●	Large trees particularly Pt with heart rot important for nesting. Downed woody debris and snags important as insect source.	Pileated Woodpecker *Dryocopus pileatus*
●	○	●	●	●	●	○	●	●	●	●	Mature poplar and spruce trees for nesting near an area of open wet muskeg. Mixedwoods used for nesting.	Great Gray Owl *Strix nebulosa*
		○	○	●	●		○	○	●	●	Prefers mature and older Sw, Sb, and Bf for forage and cover. Needs trees with heart rot for cavities to nest in.	Boreal Chickadee *Parus hudsonicus*
○	○	○	○	○	○	●	●	●	●	●	Generally considered an edge species. Prefers semi-open stands with some conifer content. Ubiquitous.	White Throated Sparrow *Zonotrichia albicollis*
●	○	●	○	○	○	○	●	○	○	○	Prefers dense Pt cover for both protection from predators and for food source (buds). Logs required for males to drum. Nests in more open and mature Pt stands and feeds on the catkins of mature Pt in winter.	Ruffed Grouse *Bonasa umbellus*
		○	○	○	○	○	○	○	○	●	Prefers young dense jack pine and Pj/Sb stands and stands with well-developed conifer shrub layer.	Spruce Grouse *Dendragapus canadensis*
●	●	●	●	○	○	●	●	●	○		Prefers well-developed hardwood canopy with deciduous shrub layer.	Least Flycatcher *Empidonax minimus*
		○	○	○	○		○	○	●	●	Requires large, living and dead conifers for nest cavities and forage (insect larvae). Found in transition and gap phases as well as burnt conifer forest (3 to 8 years post-fire).	Black-backed Woodpecker *Picoides arcticus*
		○	○	●	●		○	○	●	●	Prefers moist conifer dominated stands. Sw/Sb trees required for nesting.	Ruby-crowned Kinglet *Regulus calendula*
●	●	●	●	●	●	○	●	●	●	●	Considerable variability in literature on habitat preferences (mature conifer versus mature deciduous). Key factor may be availability of caterpillars for food.	Bay-breasted Warbler *Dendroica castanea*
●	○	●	○	○		●	●	●	○		Downed woody debris and moist microclimate important. Proximity to wetlands important for breeding.	Blue-spotted Salamander *Ambystoma laterale*

SECTION V – UNDERSTANDING THE MANAGEMENT INTERPRETATIONS

This section provides background information for using the management interpretation tables and fact sheets in Section VI. This section discusses:

- the use of the management interpretations (tables and fact sheets) in Section VI
- an approach for creating a string of silvicultural activities using the management interpretations
- regeneration standards for boreal mixedwood conditions
- an approach for verifying stand conditions using a pre-harvest assessment

Related to this section, Appendix 2 provides flowcharts and examples describing how the information in Section VI may be used to create boreal mixedwood forest units and prepare a silvicultural ground rule for developing a forest operations prescription.

Silvicultural methods and treatments discussed in Sections V and VI are defined and explained in Section III and the glossary. Management opportunities and challenges under boreal mixedwood conditions are also discussed in Section IV.

CONTEXT FOR THE MANAGEMENT INTERPRETATIONS

The management interpretations in Section VI provide information about silvicultural treatments and methods that may be used to direct a current stand condition to a desired future stand condition[1]. They were developed specifically for situations where a mixedwood stand condition has been identified through the forest management planning process as the desired future stand condition.

A number of the treatments and methods described in the management interpretations are untested operationally in boreal Ontario (Palmer, in prep.) and suggestions for their use come with appropriate cautions. These cautions are indicated by the use of a coding system in the tables and fact sheets in Section VI (see Coding Conventions, Section VI, page 2).

The cornerstone of mixedwood management is to develop and implement management strategies that emulate natural disturbances and processes (see Section I). The management interpretations have been developed to help recognize opportunities during the various stages of stand development when the natural advantages of the hardwood and conifer components of the stand may be encouraged to meet mixedwood stand objectives.

WORKING WITH THE MANAGEMENT INTERPRETATIONS: TABLES

The management interpretations in Section VI include the following tables, are colour-coded for your convenience:

- ■ Eligible Silvicultural Systems/Harvest Methods
  - at the Stem Exclusion Stage
  - at the Canopy Transition Stage
  - at the Gap Dynamics Stage
- ■ Eligible Logging Methods
- ■ Eligible Regeneration Methods
- ■ Eligible Site Preparation Methods
- ■ Eligible Silvicultural Treatments at Stand Initiation
  - ■ Eligible Tending/Cleaning Methods
- ■ Eligible Tending/Intermediate Stand Treatments at Stem Exclusion

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[1] Stand condition refers to a combination of stand composition type and stage of stand development, as defined in Section II.

Eligible Silvicultural Systems/Harvest Methods

Tables for Eligible Silvicultural Systems/Harvest Methods (Section VI, Table 1, 2, and 3) present eligible silvicultural systems and harvest methods and their suitability for securing various future stand conditions. Separate tables have been created for stands currently at the stem exclusion, canopy transition, or gap dynamics stages of stand development. To select and use the appropriate table:

- Identify the current stand composition type and the current stage of stand development.
- Select the appropriate table (Section VI, Table 1, 2, or 3) for the current stage of stand development.
- Identify the desired future stand condition for the current stand condition . When using these tables, the desired future stand condition always refers to the stand composition type occurring at the **canopy transition stage** of stand development (i.e. after harvest and regeneration).

The eligibility of each of the harvest methods to achieve the desired future stand condition is indicated by a code in the appropriate column. A page number at the bottom of each column refers to the fact sheet where further information about the harvest method may be obtained.

Eligible Logging Methods

The table for Eligible Logging Methods (Section VI, Table 4) presents the logging methods and their eligibility for use with the various silvicultural systems/harvest methods and to achieve other objectives.

The eligibility of each of the logging methods for use with each of the silvicultural systems/harvest methods or to meet other objectives, is indicated by a code in the appropriate column. A page number at the bottom of each column refers to the fact sheet where additional information about the logging method may be obtained.

Eligible Regeneration Methods

The table for Eligible Regeneration Methods (Section VI, Table 5) presents the eligible regeneration methods for directing a current stand condition to various future stand conditions. To use this table:

- Identify the current stand condition.
- Specify the desired future stand condition (stand composition type occurring at **canopy transition**) (i.e. after harvest and regeneration) for each current stand condition to determine eligible regeneration methods.

The eligibility of each of the regeneration methods to achieve the desired future stand condition is indicated by a code in the appropriate column. A page number at the bottom of each column refers to the fact sheet where further information about the regeneration method may be obtained.

Eligible Site Preparation Methods

The table for Eligible Site Preparation Methods (Section VI, Table 6) lists the eligible site preparation methods for each of the potential regeneration methods. To use the table, a proposed regeneration method must be identified.

The compatibility of each of the site preparation methods with each of the regeneration methods is indicated by a code in the appropriate column. A page number at the bottom of each column refers to the fact sheet where additional information about the site preparation method may be obtained.

Eligible Silvicultural Treatments at Stand Initiation

The table for Eligible Silvicultural Treatments at Stand Initiation (Section VI, Table 7) lists eligible silvicultural treatments applicable to stands at the stand initiation stage when a desired future stand condition (stand composition type occurring at **canopy transition**) has been identified (i.e. current rotation). To use this table:

- Identify the current stand composition type at the stand initiation stage.
- Specify the desired future stand composition type at **canopy transition** to determine eligible silvicultural treatments.

Note: A combination of eligible treatments may be required to redirect the current stand condition to the future stand condition because a single treatment may not be sufficient to alter stand composition, e.g. juvenile spacing. However, the coding indicates whether or not the treatment is deemed compatible with the selected objective.

The eligibility of each of the silvicultural treatments (cleaning, supplemental regeneration, compositional treatment, juvenile spacing, and reinitiation) is indicated by a code in the appropriate column. A page number at the bottom of each column refers to the fact sheet where additional information about the silvicultural treatment is provided.

If tending is identified as an eligible treatment at this stage, consult the Eligible Tending/Cleaning Methods table (Section VI, Table 8) (as discussed below) to select an appropriate method.

Eligible Tending/Cleaning Methods

The table for Eligible Tending/Cleaning Methods (Section VI, Table 8) lists the eligible tending/cleaning methods for each of the potential regeneration methods. To use this table the regeneration method must be identified.

The compatibility of each of the tending/cleaning methods with each of the regeneration methods is indicated by a code in the appropriate column. A page number at the bottom of each column refers to the fact sheet where further information about the tending/cleaning method may be obtained.

Eligible Tending/Intermediate Stand Treatments at Stem Exclusion

The table for Eligible Tending/Intermediate Stand Treatments at Stem Exclusion (Section VI, Table 9) lists eligible silvicultural treatments applicable to stands at the stem exclusion stage. To use this table:

- Identify the current stand composition type at the stem exclusion stage.
- Specify the desired future stand composition type at **canopy transition** (i.e. current rotation) to determine eligible treatments.

Note: A combination of eligible treatments may be required to redirect the current stand condition to the future stand condition because a single treatment may not be sufficient to alter stand composition, e.g. pre-commercial thinning. However, the coding indicates whether or not the treatment is deemed compatible with the selected objective.

The eligibility of each of the silvicultural treatments (compositional treatment, pre-commercial thinning, liberation treatment, commercial thinning) is indicated by a code in the appropriate column. A page number at the bottom of each column refers to the fact sheet where further information about each silvicultural treatment is provided.

If tending is identified as an eligible treatment at this stage, consult the Eligible Tending/Cleaning Methods table (Section VI, Table 8) (as discussed above) to select an appropriate method.

Developing Strings of Silvicultural Activities

Procedures for using the tables in Section VI to develop a string of silvicultural activities are presented in the following figures:

- Figure 1. Use of the management interpretation tables for stands eligible for harvest and regeneration.
- Figure 2. Use of the management interpretation tables for stands currently at the stand initiation stage.
- Figure 3. Use of the management interpretation tables for stands at the stem exclusion stage and not currently eligible for harvest.

Figure 1. Use of the management interpretation tables in Section VI for stands eligible for harvest and regeneration.

Current Stand Condition: Eligible for Harvest and Regeneration; at Stem Exclusion, Canopy Transition, or Gap Dynamics Stage

Confirm current stand composition type and stage of stand development.

Select appropriate Silvicultural Systems/Harvest Methods table (Table 1, 2, or 3) based on current stage of stand development.

↓

Determine desired future stand condition at canopy transition stage after harvest (i.e. next rotation):

- list Eligible Silvicultural Systems/Harvest Methods (Table 1, 2, or 3); see Workseet 1 Appendix 5
- list Eligible Logging Methods (Table 4), compatible with listed Silvicultural Systems/Harvest Methods
- list Eligible Regeneration Methods (Table 5)

↓

Consult fact sheets as appropriate.

Select Silvicultural System/Harvest Method – Logging Method – Regeneration Method combination (harvest-to-harvest silvicultural string, see Worksheet 2 Appendix 5).

↓

For selected Regeneration Method:

- list Eligible Site Preparation Methods (Table 6)

↓

Consult fact sheets as appropriate.

Select Site Preparation Method.

↓

For the regenerated stand consider:

- Eligible Silvicultural Treatments for stands at the stand initiation stage (Table 7)
- If tending/cleaning is an eligible treatment, select Eligible Tending/Cleaning Method (Table 8) for corresponding Regeneration Method.

↓

Consult fact sheets as appropriate.

Select Silvicultural Treatment(s).

Select Tending/Cleaning Methods.

↓

For the regenerated stand consider:

- Eligible Silvicultural Treatments for stands at the stem exclusion stage (Table 9)
- If tending/cleaning is an eligible treatment, select Eligible Tending/Cleaning Method (Table 8) for corresponding Regeneration Method.

↓

Consult fact sheets as appropriate.

Select treatments for stands at the stem exclusion stage.

↓

Select and record appropriate methods and treatments to meet objectives (i.e. a complete harvest-to-harvest string of silvicultural activities).

Figure 2. Use of the management interpretation tables in Section VI for stands currently at the **Stand Initiation** stage.

Current Stand Condition: At the stand initiation stage as a result of harvest, regeneration treatment, or natural disturbance (e.g. fire, blowdown)

Confirm current stand composition type and stage of stand development.

↓

Determine desired future stand condition at the canopy transition stage (i.e. current rotation).

↓

List Eligible Silvicultural Treatments at the stand initiation stage (Table 7); see Worksheet 1 Appendix 5:

- Cleaning
- Supplemental Regeneration
- Compositional Treatment
- Juvenile Spacing
- Reinitiation
- If tending/cleaning is an eligible treatment, select Eligible Tending/Cleaning Method (Table 8) for corresponding Regeneration Method.

↓

Consult fact sheets as appropriate.

Select and record appropriate treatments to meet objectives; see Worksheet 2 Appendix 5.

Figure 3. Use of the management interpretation tables in Section VI for stands at the **Stem Exclusion** stage and not currently eligible for harvest.

Current Stand Condition: At stem exclusion stage and not currently eligible for harvest

Confirm current stand composition type and stage of stand development.

↓

Determine desired future stand condition at canopy transition stage (i.e. current rotation).

↓

List Eligible Silvicultural Treatments at the stem exclusion stage (Table 9); see Worksheet 1 Appendix 5:

- Compositional Treatment
- Pre-commercial Thinning
- Liberation Treatment
- Commercial Thinning

If tending is an eligible treatment, select Eligible Tending/Cleaning Method (Table 8) for corresponding Regeneration Method.

↓

Consult fact sheets as appropriate.

Select and record appropriate treatments to meet objectives; see Worksheet 2 Appendix 5.

WORKING WITH THE MANAGEMENT INTERPRETATIONS: FACT SHEETS

The management interpretations in Section VI include the following fact sheets, are colour-coded for your convenience:

■ Silvicultural Systems/Harvest Methods

□ Logging Methods

■ Regeneration Methods

□ Site Preparation Methods

■ Tending/Cleaning Methods

■ Tending/Intermediate Stand Treatments

Figure 4 describes the information presented in a fact sheet and how it is used.

Regeneration Standards

Requirements and terminology for describing regeneration standards in Ontario are outlined in *Silvicultural Effectiveness Monitoring Manual for Ontario* (OMNR 2001c). Additional considerations for boreal mixedwood objectives are:

- target and acceptable species must:
  - be compatible with each other
  - be compatible with the ecological conditions of the site and conditions (e.g. light regime) modified by the silvicultural system and harvest method
  - contribute to the management objectives
- minimum heights:
  - are critical attributes for the conifer component of the mixedwood stand
  - must be specified for advance growth; and additional criteria for acceptable advance growth should be specified to ensure their ability to respond to release and their suitability as future crop trees

Figure 4. Information provided in a management interpretation fact sheet.

Title: Identifies the silvicultural method or treatment.	
Overview	This section provides a brief summary of general information pertaining to a method or treatment and indicates its applicability under particular conditions. Definitions and detailed explanations of the methods and treatments are provided in Section III.
Promotion of Conifer	This section highlights procedures, observations, or other information to indicate the opportunities for using the method/treatment to promote the conifer component of a boreal mixedwood stand.
Promotion of Hardwood	This section highlights procedures, observations, or other information to indicate the opportunities for using the method/treatment to promote the hardwood component of a boreal mixedwood stand.
CR Conditionally Recommended Practices	This section describes the "conditions" that must be met to implement a method/treatment designated as "CR" (see Coding Conventions in Section VI). A "CR" may indicate a condition applicable to a specific treatment or to a general condition that applies where appropriate, across all boreal mixedwood site and/or stand conditions covered by this guide. The conditions are not numbered to correspond to specific site or stand conditions. Each condition should be reviewed and evaluated to determine its applicability to the specific circumstances being considered.
D Developmental Practices	This section contains background information that **may** be useful in developing an approach suitable for boreal Ontario conditions. This information has been determined from literature reviews or from summaries of preliminary research results (see Coding Conventions in Section VI). The category "D" was developed for this guide because of the large number of practices that were untested operationally in mixedwood conditions in boreal Ontario but showed promise. The information in this section does not necessarily comprise a preferred option for boreal Ontario conditions. When planning a developmental practice, "conditions" listed in the "CR" section must be reviewed and applied, if applicable, to the developmental practice.
NR Not Recommended Practices	Comments in this section indicate why certain practices have been classified as "NR" (see Coding Conventions in Section VI). In some cases, "NR" may indicate that an activity is not ecologically appropriate or will not lead to the management objectives. In those instances, the reason for the NR designation may not be indicated on individual fact sheets.
Considerations for Implementation	This section presents information that is important to consider when implementing a recommended ("R") method or treatment (see Coding Conventions in Section VI). Additional information concerning the implementation of an "R" method or treatment is provided in Sections III and IV. Comments in this section should be considered for application to all categories of treatment ("R", "CR", "NR", or "D").
Opportunities	This section reports other information that may be considered in determining the appropriateness of a treatment in boreal Ontario conditions. The following information may be outlined in this section: opportunities to link to other methods/treatments, variations in the application of the method/treatment that have been attempted, opportunities for pre-harvest treatments (including site preparation, planting, and tending), potential benefits of the method/treatment, and comments indicating how the method/treatment emulates some aspect of a natural disturbance.
Go To	This section provides a link to additional tables and/or fact sheets that should be considered when evaluating silvicultural options.

- timing:
  - years to free-to-grow should be specified for clearcut and shelterwood silvicultural systems
  - years since last disturbance may be used to define assessment periods for selection silvicultural systems
- minimum and maximum density levels:
  - should be defined as they relate to the achievement of management objectives
  - will influence wood quality and the yield of specific size classes or products
- selected methodologies to assess regeneration:
  - should provide confidence limits suitable for the management decisions being made

Regeneration Standards for Developing Aspen Stands with Conifer Understories

Conifers growing in intimate mixtures with shade intolerant hardwoods (i.e. conifers in the understorey of a developing hardwood overstorey) may undergo intense competition due to differences in juvenile height growth. In these situations, it is important that the competition between species is managed so that conifer regeneration receives adequate resources, particularly light, for their survival and growth. In developing aspen stands, the lowest period of light transmission appears to occur between the ages of 15 and 25 years, and may be as low as four percent of full sunlight—far below the level of light required for spruce survival (Pinno *et al.* 2001, Lieffers *et al.* 2002, Comeau 2001).

Traditional methods of free-to-grow assessment, using small assessment plots and "distance to competition" rules, are not able to predict the competitive impacts of aspen for light in these situations (Lieffers *et al.* 2002). It was determined that larger assessment plots, related to the size of the aspen trees, would be required to assess light competition using a traditional "tree centre" approach. However, at the time of the "light bottleneck", it was concluded that the size of the assessment plots required would be operationally impractical (e.g. require 10 metre diameter assessment plots). Indices based on stand parameters (e.g. stand density and size, or stand basal area) of the developing aspen stand show promise as a better indication of light transmission to the understorey spruce than current free-to-grow criteria (Lieffers *et al.* 2002).

Therefore, as an alternative to traditional free-to-grow assessments, limits on the density of aspen (related to stand height) may be appropriate for describing criteria when spruce and aspen are growing in intimate mixtures. Aspen stands up to 30 years in age may be assessed using this stand average approach to ensure adequate light levels during the lowest period of light transmission (Lieffers *et al.* 2002, Comeau 2001). Any standards based on this approach should be evaluated for Ontario conditions, and the density and size of aspen stands should be assessed and related to measured light transmission levels in the understorey.

Verifying Forest Operation Prescriptions for Mixedwood Management

Many of the stand and site attributes critical to the successful implementation of a boreal mixedwood silvicultural strategy (e.g. stage of stand development, broad soil group, stand composition type, understorey composition, and presence of advance growth) may not be determined from Ontario's forest resource inventory (FRI), which is currently completed in the boreal forest using leaf-on, black-and-white photography at a scale of 1:20,000. For the successful implementation of a mixedwood prescription, important ecological attributes (e.g. ecosites), as well as the traditional inventory descriptions (e.g. stocking, stand age, volumes) must be verified. This information is normally confirmed through a field based pre-harvest assessment.

The pre-harvest assessment is a field inspection designed to identify the opportunities and constraints that may influence the successful implementation of a boreal mixedwood silvicultural ground rule for a specific stand or group of stands. Some of the key factors that should be assessed include:

- broad soil group and Forest Ecosystem Classification (FEC) soil type

- tree species composition of the canopy, subcanopy, and understorey layers
- understorey vegetation and FEC vegetation type
- stage of stand development
- opportunities for tree regeneration, including the potential for vegetative reproduction, natural seeding, advance growth, and artificial treatments
- identification of potential damaging agents such as disease
- other site constraints or opportunities
- wildlife values

Important Considerations in Designing Pre-harvest Assessment Procedures

Step-by-step procedures have been described for the completion of pre-harvest assessments in the boreal forest (Towill *et al.* 1988, Bidwell *et al.* 1996). An example of a pre-harvest assessment form is provided in Appendix 5. The following procedures emphasize conditions that should be assessed when completing a pre-harvest assessment for the potential application of a boreal mixedwood silvicultural prescription.

Sampling Methodology

A "free survey" (Towill *et al.* 1988) is one recommended sampling design in which the selection of sample points along transects is designed to capture "significant" variation in conditions relevant to the use of the management interpretation tables and fact sheets.

Transects should be predetermined on aerial photographs to capture significant variability that may occur within the stand. Excessive variability in important site and stand attributes may require stratification of the stand and completion of separate pre-harvest assessment documentation.

Data from sample points should be supplemented with a "walk through" assessment to determine variability of conditions. The data that should be collected at each sample point are as follows (adapted from Maurer 1995).

Canopy and Sub-canopy Conditions

- at sample points, conduct prism sweep and tally by species; for three dominant canopy trees, record dbh, total height, and age at breast height
- resulting basal area sample defines species composition and stocking
- one 400 square metre plot (11.28 metre radius) is used to determine density of canopy and sub-canopy trees by species; this plot should use the same plot centre as the prism plot (above)
- attributes to be recorded may include: species, height, age, stocking, density, and site class

Understorey Shrub Layer Conditions

- record coverage of shrub species by height class
- attributes to be recorded include: species, height class, and percent cover

Advance Regeneration

- at a sampling point, establish a 50 square metre plot (3.99 metre radius) and count, by species and height class, all trees considered to be advance growth
- attributes to be recorded include: stems per hectare of advance regeneration by species and height class

Soil Attributes

- at each sample plot, record soil attributes such as organic matter depth, humus form, depth to restrictive layer, moisture regime/drainage, depth to mottles/gley and soil texture class, using FEC conventions

FEC Vegetation and Soil Types and Ecosite

- determine FEC V-type and S-type and ES-type using FEC/ELC classification procedures

Windthrow Risk

- using the slenderness coefficient and other criteria, assess and record windthrow risk for canopy and sub-canopy trees by species

Strata/Stand Summary Information

Attributes to be summarized for the strata/stand are:

- canopy composition (stocking by species)
- sub-canopy composition (stocking by species)
- stage of stand development
- current stand condition
- broad soil group

Draft Pre-harvest Prescription

A pre-harvest prescription form (see example in Appendix 5) may be completed while in the field; this provides an opportunity to record the extent and magnitude of any opportunities or constraints for silvicultural activities while it is still possible to verify on-site conditions. The following information should be recorded:

Objectives

- desired stand composition and structural objectives, future stand condition and additional stand attributes that characterize the future stand objective

Harvesting Plan

- silvicultural system, preferred harvest method and compatible logging method
- proposed scheduling of partial cuts for selection and shelterwood
- seasonal restrictions
- kind and species of trees to be cut
- kind and species of residual and rationalization
- volume/products expected
- access
- constraints and other special conditions

Renewal Plan

- preferred and alternative regeneration methods
- microsite objective and site preparation method
- regeneration method
- target densities
- tending objective and method
- constraints and rationale for all renewal treatments

Monitoring

- type of survey and schedule for monitoring the developing stand

SECTION VI – MANAGEMENT INTERPRETATIONS

Section VI presents the following management interpretations:

Tables

- ■ Eligible Silvicultural Systems/Harvest Methods
  - at Stem Exclusion
  - at Canopy Transition
  - at Gap Dynamics
- ■ Eligible Logging Methods
- ■ Eligible Regeneration Methods
- ■ Eligible Site Preparation Methods
- ■ Eligible Silvicultural Treatments at Stand Initiation
  - ■ Eligible Tending/Cleaning Methods
- ■ Eligible Tending/Intermediate Stand Treatments at Stem Exclusion

Fact Sheets

- ■ Silvicultural Systems/Harvest Methods
  - Clearcut Harvest Method
  - Shelterwood Harvest Method
  - Selection Harvest Method
- ■ Logging Methods
- ■ Regeneration Methods
  - Natural
  - Artificial
- ■ Site Preparation Methods
- ■ Tending/Cleaning Methods and Additional Silvicultural Treatments at Stand Initiation
- ■ Tending/Intermediate Stand Treatments

Coding Conventions

On each of the management interpretation tables, the eligibility of each of the silvicultural methods or treatments is indicated by a code. These codes are also referred to on the fact sheets. The code identifies the method or treatment as recommended (R), conditionally recommended (CR), developmental (D), not recommended (NR), or excluded (X).

The definitions for these terms are:

R – Recommended

This activity is ecologically appropriate (it relates well to the biology of the species, the conditions of the site type, and minimizes the potential for damage to the physical environment) and can contribute to the management objectives. Recommended means that the activity can work based on field experience and current knowledge for boreal Ontario. Recommended does not necessarily suggest that this activity is the best or only option from a biological, ecological, or management objective perspective.

CR – Conditionally Recommended

This activity is ecologically appropriate (it relates well to the biology of the species, the conditions of the site type, and minimizes the potential for damage to the physical environment), can contribute to the management objectives, and can work based on field experience and current knowledge for boreal Ontario **only if the conditions or limitations referenced in the "CR" section of the fact sheet are addressed.** The conditions or limitations in the "CR" section of the fact sheet must be addressed each and every time the activity is referenced in the silvicultural ground rules or in a specific silvicultural treatment package. Otherwise, use of the activity is not recommended and triggers the exception process of the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996).

NR – Not Recommended

This activity is not ecologically appropriate (it does not relate well to the biology of the species or the condition of the site type or there is potential for damage to the physical environment), will not contribute to the management objectives, or is not supported by field experience or current knowledge of its application under boreal conditions. Selection of this activity in the silvicultural ground rules or in a specific silvicultural treatment package triggers the exception process of the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996).

D – Developmental

This activity is not supported by field experience or by current knowledge of its application in boreal Ontario. However, the treatment has been tried in boreal mixedwood conditions in other jurisdictions, is part of an active, on-going research and development program, is the subject of a trial that has yielded encouraging preliminary short-term results, or is considered promising based on an understanding of the biology of the species and conditions of the site type. The implication with this designation is that the activity shows promise as a "best bet" for an operational method or treatment in Ontario's boreal forest but requires further investigation and monitoring. A developmental activity may include and must consider conditional recommendations specified for the method or treatment. The selection of this activity in the silvicultural ground rules or in a specific silvicultural treatment package triggers the exception process of the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996) and requires a provincially-designed and coordinated monitoring procedure.

X – Excluded

This activity is not an option because the current stand condition is rare or does not exist, the future stand condition does not exist, or the activity is not permitted in this version of the guide due to a high risk of misapplication which would result in stand or site degradation.

Tables

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■ Table 2. Eligible Silvicultural Systems/Harvest Methods at **Canopy Transition** ... 6
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Table 1. Eligible Silvicultural Systems/Harvest Methods at STEM EXCLUSION.

Silvicultural System →		Clearcut				Shelterwood			Selection	
Current Stand Condition	Future Stand Condition* / Harvest Method	Conventional	with Standards	Seed Tree	Two-stage	Uniform	Strip	Group	Individual	Group
Aspen pure and/or dominated	Aspen dominated	R	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	X	X	X	X	X	X	X	X	X
	Aspen leading	R	D	NR	D	D	D	NR	X	X
	Birch leading	X	X	X	X	X	X	X	X	X
	Softwood leading	CR	D	D	D	D	D	D	NR	NR
	Softwood dominated	CR	D	D	D	D	D	D	NR	NR
Birch pure and/or dominated	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	R	NR	D	NR	D	D	D	X	X
	Aspen leading	CR	D	NR	D	NR	NR	NR	X	X
	Birch leading	R	NR	D	NR	D	D	D	NR	NR
	Softwood leading	CR	NR	D	D	D	D	D	NR	NR
	Softwood dominated	CR	NR	D	D	D	D	D	NR	NR
Aspen leading	Aspen dominated	R	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	X	X	X	X	X	X	X	X	X
	Aspen leading	R	D	NR	D	NR	NR	NR	X	X
	Birch leading	CR	D	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	D	D	D	D	D	D	NR	NR
	Softwood dominated	CR	D	D	D	D	D	D	NR	NR
Go to Page →		**20**	**22**	**24**	**26**	**28**	**28**	**31**	**33**	**35**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 1. Eligible Silvicultural Systems/Harvest Methods at STEM EXCLUSION (cont.).

Silvicultural System →		Clearcut				Shelterwood			Selection	
Current Stand Condition	**Future Stand Condition*** / **Harvest Method**	**Conventional**	**with Standards**	**Seed Tree**	**Two-stage**	**Uniform**	**Strip**	**Group**	**Individual**	**Group**
Birch leading	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	CR	NR	D	NR	D	D	D	X	X
	Aspen leading	CR	D	NR	NR	NR	NR	NR	X	X
	Birch leading	CR	NR	D	NR	D	D	D	NR	NR
	Softwood leading	CR	NR	D	D	D	D	D	NR	NR
	Softwood dominated	CR	NR	D	D	D	D	D	NR	NR
Softwood leading	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	NR	NR	D	NR	NR	NR	NR	X	X
	Aspen leading	CR	D	NR	D	NR	NR	NR	X	X
	Birch leading	CR	NR	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	D	D	D	D	D	D	NR	NR
	Softwood dominated	CR	D	D	D	D	D	D	NR	NR
Softwood dominated	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	NR	NR	D	NR	NR	NR	NR	X	X
	Aspen leading	CR	D	NR	D	NR	NR	NR	X	X
	Birch leading	NR	NR	D	NR	NR	NR	NR	NR	NR
	Softwood leading mix	CR	D	D	D	D	D	D	NR	D
	Softwood dominated	CR	D	D	D	D	D	D	D	D
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R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 2. Eligible Silvicultural Systems/Harvest Methods at CANOPY TRANSITION.

Silvicultural System →		Clearcut				Shelterwood			Selection	
Current Stand Condition	Future Stand Condition* / Harvest Method	Conventional	with Standards	Seed Tree	Two-stage	Uniform	Strip	Group	Individual	Group
Aspen pure and/or dominated	Aspen dominated	R	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	X	X	X	X	X	X	X	X	X
	Aspen leading	R	D	NR	D	NR	NR	NR	X	X
	Birch leading	X	X	X	X	X	X	X	X	X
	Softwood leading	CR	D	D	D	D	D	D	NR	NR
	Softwood dominated	CR	D	D	D	D	D	D	NR	NR
Birch pure and/or dominated	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	R	NR	D	NR	D	D	D	X	X
	Aspen leading	CR	D	NR	D	NR	NR	NR	X	X
	Birch leading	R	NR	D	NR	D	D	D	NR	NR
	Softwood leading	CR	NR	D	D	D	D	D	NR	NR
	Softwood dominated	CR	NR	D	D	D	D	D	NR	NR
Aspen leading	Aspen dominated	R	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	X	X	X	X	X	X	X	X	X
	Aspen leading	R	D	NR	D	NR	NR	NR	X	X
	Birch leading	CR	D	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	D	D	D	D	D	D	NR	NR
	Softwood dominated	CR	D	D	D	D	D	D	NR	NR
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R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 2. Eligible Silvicultural Systems/Harvest Methods at CANOPY TRANSITION (cont.).

Silvicultural System →		Clearcut				Shelterwood			Selection	
Current Stand Condition	**Harvest Method / Future Stand Condition***	**Conventional**	**with Standards**	**Seed Tree**	**Two-stage**	**Uniform**	**Strip**	**Group**	**Individual**	**Group**
Birch leading	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	CR	NR	D	NR	D	D	D	X	X
	Aspen leading	CR	D	NR	NR	NR	NR	NR	X	X
	Birch leading	CR	NR	D	NR	D	D	D	NR	NR
	Softwood leading	CR	NR	D	D	D	D	D	NR	NR
	Softwood dominated	CR	NR	D	D	D	D	D	NR	NR
Softwood leading	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	NR	NR	D	NR	NR	NR	NR	X	X
	Aspen leading	CR	D	NR	D	NR	NR	NR	X	X
	Birch leading	CR	NR	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	D	D	D	D	D	D	D	D
	Softwood dominated	CR	D	D	D	D	D	D	D	D
Softwood dominated	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	NR	NR	D	NR	NR	NR	NR	X	X
	Aspen leading	CR	D	NR	D	NR	NR	NR	X	X
	Birch leading	NR	NR	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	D	D	D	D	D	D	NR	D
	Softwood dominated	CR	D	D	D	D	D	D	D	D
Go to Page →		**20**	**22**	**24**	**26**	**28**	**28**	**31**	**33**	**35**

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* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 3. Eligible Silvicultural Systems/Harvest Methods at GAP DYNAMICS.

Silvicultural System →		Clearcut				Shelterwood			Selection	
Current Stand Condition	Harvest Method / Future Stand Condition*	Conventional	with Standards	Seed Tree	Two-stage	Uniform	Strip	Group	Individual	Group
Aspen pure and/or dominated	Aspen dominated	X	X	X	X	X	X	X	X	X
	Birch dominated	X	X	X	X	X	X	X	X	X
	Aspen leading	X	X	X	X	X	X	X	X	X
	Birch leading	X	X	X	X	X	X	X	X	X
	Softwood leading	X	X	X	X	X	X	X	X	X
	Softwood dominated	X	X	X	X	X	X	X	X	X
Birch pure and/or dominated	Aspen dominated	X	X	X	X	X	X	X	X	X
	Birch dominated	X	X	X	X	X	X	X	X	X
	Aspen leading	X	X	X	X	X	X	X	X	X
	Birch leading	X	X	X	X	X	X	X	X	X
	Softwood leading	X	X	X	X	X	X	X	X	X
	Softwood dominated	X	X	X	X	X	X	X	X	X
Aspen leading	Aspen dominated	X	X	X	X	X	X	X	X	X
	Birch dominated	X	X	X	X	X	X	X	X	X
	Aspen leading	X	X	X	X	X	X	X	X	X
	Birch leading	X	X	X	X	X	X	X	X	X
	Softwood leading	X	X	X	X	X	X	X	X	X
	Softwood dominated	X	X	X	X	X	X	X	X	X
Go to Page →		20	22	24	26	28	28	31	33	35

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 3. Eligible Silvicultural Systems/Harvest Methods at GAP DYNAMICS (cont.).

Silvicultural System →		Clearcut				Shelterwood			Selection	
Current Stand Condition	Harvest Method / Future Stand Condition*	Conventional	with Standards	Seed Tree	Two-stage	Uniform	Strip	Group	Individual	Group
Birch leading	Aspen dominated	CR	D	NR	NR	NR	NR	NR	X	X
	Birch dominated	CR	NR	D	NR	NR	NR	NR	X	X
	Aspen leading	CR	D	NR	NR	NR	NR	NR	X	X
	Birch leading	CR	NR	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	NR	D	NR	D	D	D	NR	NR
	Softwood dominated	CR	NR	D	NR	D	D	D	NR	NR
Softwood leading	Aspen dominated	CR	NR	NR	NR	NR	NR	NR	X	X
	Birch dominated	NR	NR	D	NR	NR	NR	NR	X	X
	Aspen leading	CR	NR	NR	NR	NR	NR	NR	X	X
	Birch leading	CR	NR	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	NR	D	NR	NR	NR	NR	D	D
	Softwood dominated	CR	NR	D	NR	NR	NR	NR	D	D
Softwood dominated	Aspen dominated	CR	NR	NR	NR	NR	NR	NR	NR	X
	Birch dominated	NR	NR	D	NR	NR	NR	NR	NR	NR
	Aspen leading	CR	NR	NR	NR	NR	NR	NR	NR	X
	Birch leading	NR	NR	D	NR	NR	NR	NR	NR	NR
	Softwood leading	CR	NR	D	NR	NR	NR	NR	NR	D
	Softwood dominated	CR	NR	D	NR	NR	NR	NR	D	D
Go to Page →		**20**	**22**	**24**	**26**	**28**	**28**	**31**	**33**	**35**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 4. Eligible Logging Methods.

Harvest Method/Treatment Objective	Full-Tree	Tree-Length	Cut-to-Length
Conventional Clearcut	R	R	R
Clearcut with Standards	R	R	R
Seed Tree	R	R	R
Two-stage	NR	CR	CR
Uniform Shelterwood	NR	CR	CR
Strip Shelterwood (overstorey removed; shelter from adjacent strips)	CR	CR	CR
Strip Shelterwood (shelter from overstorey)	NR	CR	CR
Group Shelterwood (overstorey removed; shelter from adjacent trees)	CR	CR	CR
Group Shelterwood (shelter from overstorey)	NR	CR	CR
Individual Tree Selection	NR	CR	CR
Group Selection	NR	CR	CR
Compositional Treatment (harvest)	NR	CR	CR
Commercial Thinning	NR	CR	CR
Liberation Treatment (harvest)	NR	CR	CR
Reduction of Compaction and Rutting	CR	CR	CR
Protection of Advance Growth	NR	CR	CR
Go to Page →	**37**	**37**	**37**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

Table 5. Eligible Regeneration Methods.

Regeneration Type →		Natural			Artificial			
Current Stand Condition	Regeneration Method / Future Stand Condition*	Advance Growth	Seed	Vegetative/ Coppice	Pre-harvest Underplant	Post-harvest Plant	Cluster Planting	Direct Seed
Aspen pure and/or dominated	Aspen dominated	CR	NR	R	D	NR	CR	NR
	Birch dominated	X	X	X	X	X	X	X
	Aspen leading	CR	NR	R	D	CR	CR	NR
	Birch leading	X	X	X	X	X	X	X
	Softwood leading	CR	D	R	D	CR	CR	NR
	Softwood dominated	CR	D	R	D	CR	NR	NR
Birch pure and/or dominated	Aspen dominated	CR	NR	CR	D	NR	CR	NR
	Birch dominated	CR	D	CR	D	NR	CR	D
	Aspen leading	CR	NR	CR	D	CR	CR	NR
	Birch leading	CR	D	CR	D	CR	CR	D
	Softwood leading	CR	D	R	D	CR	CR	NR
	Softwood dominated	CR	D	R	D	CR	NR	NR
Aspen leading	Aspen dominated	CR	NR	R	D	NR	CR	NR
	Birch dominated	X	X	X	X	X	X	X
	Aspen leading	CR	NR	R	D	CR	CR	NR
	Birch leading	CR	D	CR	D	CR	CR	D
	Softwood leading	CR	D	R	D	CR	CR	NR
	Softwood dominated	CR	D	R	D	CR	NR	NR
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R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 5. Eligible Regeneration Methods (cont.).

Regeneration Type →		Natural			Artificial			
Current Stand Condition	**Future Stand Condition* / Regeneration Method**	**Advance Growth**	**Seed**	**Vegetative/ Coppice**	**Pre-harvest Underplant**	**Post-harvest Plant**	**Cluster Planting**	**Direct Seed**
Birch leading	Aspen dominated	CR	NR	CR	D	NR	CR	NR
	Birch dominated	CR	D	CR	D	NR	CR	D
	Aspen leading	CR	NR	CR	D	CR	CR	NR
	Birch leading	CR	D	R	D	CR	CR	D
	Softwood leading	CR	D	R	D	CR	CR	NR
	Softwood dominated	CR	D	R	D	CR	NR	NR
Softwood leading	Aspen dominated	CR	NR	CR	D	NR	CR	NR
	Birch dominated	CR	D	CR	D	NR	CR	D
	Aspen leading	CR	NR	R	D	CR	CR	NR
	Birch leading	CR	D	R	D	CR	CR	D
	Softwood leading	CR	D	R	D	CR	CR	NR
	Softwood dominated	CR	D	R	D	CR	NR	NR
Softwood dominated	Aspen dominated	CR	NR	R	D	NR	CR	NR
	Birch dominated	CR	D	CR	D	NR	CR	D
	Aspen leading	CR	NR	R	D	CR	CR	NR
	Birch leading	CR	D	CR	D	CR	CR	D
	Softwood leading	CR	D	R	D	CR	CR	CR
	Softwood dominated	CR	D	R	D	CR	NR	CR
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R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. after harvest and renewal).

Table 6. Eligible Site Preparation Methods.

Regeneration Type	Regeneration Method	Site Preparation Method				
		Manual/ Motor-manual	Mechanical	Chemi-Mechanical	Chemical	Prescribed Burning
Natural	Advance[1] Growth	X	X	X	X	X
	Seed	NR	CR	CR	NR	CR
	Vegetative/ Coppice	NR	CR	CR	NR	CR
Artificial	Pre-harvest Treatments	CR	D	D	D	NR
	Post-harvest Plant	R	CR	CR	CR	CR
	Cluster Planting	R	CR	CR	CR	CR
	Direct Seed	CR	CR	CR	NR	R
Go to Page →		**51**	**52**	**52**	**55**	**57**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

[1] Site preparation is designated "X" for advance growth because advance growth is established on a site prior to application of site preparation. Some site preparation methods are compatible with protection of advance growth (see fact sheets).

Table 7. Eligible Silvicultural Treatments at STAND INITIATION.

Current Stand Condition	Future Stand Condition*	Silvicultural Treatment				
		Cleaning (Chemical)	Supplemental Regeneration	Compositional Treatment	Juvenile Spacing	Reinitiate
Aspen pure and/or dominated	Aspen dominated	NR	NR	X	CR	R
	Birch dominated	X	X	X	X	X
	Aspen leading	R	R	CR	CR	R
	Birch leading	X	X	X	X	X
	Softwood leading	R	R	CR	D	R
	Softwood dominated	R	R	CR	D	R
Birch pure and/or dominated	Aspen dominated	NR	NR	CR	X	R
	Birch dominated	R	D	X	D	R
	Aspen leading	R	R	CR	X	R
	Birch leading	R	R	CR	D	R
	Softwood leading	R	R	CR	D	R
	Softwood dominated	R	R	CR	D	R
Aspen leading	Aspen dominated	R	CR	CR	CR	R
	Birch dominated	X	X	X	X	X
	Aspen leading	R	R	X	CR	R
	Birch leading	X	X	X	X	X
	Softwood leading	R	R	CR	D	R
	Softwood dominated	R	R	CR	D	R
Go to Page →		60	62	64	65	63

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. current rotation).

Table 7. Eligible Silvicultural Treatments at STAND INITIATION (cont.).

Current Stand Condition	Future Stand Condition*	Silvicultural Treatment				
		Cleaning (Chemical)	Supplemental Regeneration	Compositional Treatment	Juvenile Spacing	Reinitiate
Birch leading	Aspen dominated	NR	NR	CR	X	R
	Birch dominated	R	D	CR	D	R
	Aspen leading	R	R	CR	X	R
	Birch leading	R	R	X	D	R
	Softwood leading	R	R	CR	D	R
	Softwood dominated	R	R	CR	D	R
Softwood leading	Aspen dominated	NR	CR	CR	NR	R
	Birch dominated	R	D	CR	NR	R
	Aspen leading	R	R	CR	NR	R
	Birch leading	R	D	CR	NR	R
	Softwood leading	R	R	X	NR	R
	Softwood dominated	R	R	CR	NR	R
Softwood dominated	Aspen dominated	NR	CR	NR	NR	R
	Birch dominated	NR	CR	NR	NR	CR
	Aspen leading	NR	CR	NR	NR	R
	Birch leading	NR	CR	NR	NR	CR
	Softwood leading	R	R	CR	NR	R
	Softwood dominated	R	R	X	NR	R
Go to Page →		**60**	**62**	**64**	**65**	**63**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. current rotation).

Table 8. Eligible Tending/Cleaning Methods.

Regeneration Type	Regeneration Method	Tending/Cleaning Method		
		Manual, Motor-manual, and Mechanical	Chemical	
			Selective Application	Broadcast Application
Natural	Advance Growth	R	CR	CR
	Seed	R	CR	CR
	Vegetative/ Coppice	R	NR	NR
Artificial	Pre-harvest Underplant	R	D	D
	Post-harvest Plant	R	CR	CR
	Cluster Planting	R	CR	CR
	Direct Seed	R	CR	CR
Go to Page →		**51**	**60**	**60**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

Note: Tending includes compositional treatment, pre-commercial thinning, liberation treatment, and commercial thinning. Cleaning is an operation to free favoured trees from undesireable individuals of similar age and size which overtop them or are likely to do so (adapted OMNR 1996).

Table 9. Eligible Tending/Intermediate Stand Treatments at STEM EXCLUSION.

Current Stand Condition	Future Stand Condition*	Silvicultural Treatment			
		Compositional Treatment	Pre-commercial Thinning	Liberation Treatment	Commercial Thinning
Aspen pure and/or dominated	Aspen dominated	X	CR	NR	NR
	Birch dominated	X	X	X	X
	Aspen leading	CR	CR	NR	NR
	Birch leading	X	X	X	X
	Softwood leading	NR	D	R	NR
	Softwood dominated	NR	D	R	NR
Birch pure and/or dominated	Aspen dominated	R	X	NR	NR
	Birch dominated	X	D	NR	NR
	Aspen leading	CR	X	NR	NR
	Birch leading	CR	D	NR	NR
	Softwood leading	NR	D	R	NR
	Softwood dominated	NR	D	R	NR
Aspen leading	Aspen dominated	R	CR	X	X
	Birch dominated	X	X	X	X
	Aspen leading	X	CR	NR	NR
	Birch leading	CR	X	NR	NR
	Softwood leading	R	D	R	NR
	Softwood dominated	NR	D	R	NR
Go to Page →		**64**	**65**	**67**	**69**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. current rotation).

Table 9. Eligible Tending/Intermediate Stand Treatments at STEM EXCLUSION (cont.).

Current Stand Condition	Future Stand Condition*	Silvicultural Treatment			
		Compositional Treatment	Pre-commercial Thinning	Liberation Treatment	Commercial Thinning
Birch leading mix	Aspen dominated	R	X	NR	X
	Birch dominated	R	D	NR	X
	Aspen leading	CR	X	NR	NR
	Birch leading	X	D	NR	NR
	Softwood leading	R	D	R	NR
	Softwood dominated	NR	D	R	NR
Softwood leading	Aspen dominated	X	NR	X	X
	Birch dominated	X	NR	X	X
	Aspen leading	X	NR	X	X
	Birch leading	X	NR	X	X
	Softwood leading	X	NR	R	D
	Softwood dominated	R	NR	R	D
Softwood dominated	Aspen dominated	X	NR	X	X
	Birch dominated	X	NR	X	X
	Aspen leading	X	NR	X	X
	Birch leading	X	NR	X	X
	Softwood leading	CR	NR	R	NR
	Softwood dominated	X	NR	R	D
Go to Page →		**64**	**65**	**67**	**69**

R = Recommended CR = Conditionally Recommended NR = Not Recommended D = Developmental X = Excluded

* Future stand condition indicates the desired stand composition type at **canopy transition** (i.e. current rotation).

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Silvicultural System: Clearcut Harvest Method: Conventional Clearcut

	Comments
Overview	• clearcutting may occur in strips, blocks, or patches
Promotion of Conifer	• artificial regeneration, particularly planting, and follow-up tending is often required to establish a conifer component on conventionally clearcut sites • generally there is insufficient natural spruce regeneration in large, upland clearcuts (Groot *et al.* 2001) in the absence of live residual seed trees • some spruce may be established from seed sources adjacent to the cut and/or remain as advance regeneration (Groot *et al.* 2001); seed fall typically shows a gradual decline within one tree height from the source edge, followed by a rapid decline thereafter (Greene *et al.* 1999) • clearcutting may be in patches or strips to improve opportunities for adequate seed dispersal of spruce, with strip cuts ≥100 m in width effectively eliminating seed dispersal constraints (Greene *et al.* 1999) • site preparation will generally be required to provide sufficient receptive seedbeds (Groot *et al.* 2001)
Promotion of Hardwood	• conventional clearcutting favours the vigorous vegetative reproduction of shade-intolerant hardwood species (aspen root suckering is stimulated when parent trees are harvested and full sunlight warms the soil in the rooting zone (Peterson and Peterson 1995); birch sprouting is also stimulated when parent trees are cut (Peterson *et al.* 1997) • when aspen and/or birch are in sufficient quantities in the pre-harvest stand, the rapid juvenile height growth rates of their suckers and sprouts in full sunlight will tend to move the site towards a hardwood leading or hardwood dominated stand condition • site preparation (scarification) is nearly always necessary to ensure adequate regeneration of birch by seed in strip cuts (Peterson *et al.* 1997)
CR Conditionally Recommended Practices	• require 100 to 120 aspen stems/ha (Davidson *et al.* 1988), or 20% basal area of aspen, that are well distributed throughout the pre-harvest stand to provide for adequate vegetative reproduction of aspen to meet the aspen dominated or leading future stand condition • require that the conifer component be monitored at appropriate intervals and tended, if required, to ensure conifers will make up the desired composition of the future stand condition • if reproducing white birch by stump sprouts, require sufficient, well distributed vigorous birch stems in the pre-harvest stand to meet compositional requirements in the birch dominated or birch leading future stand condition
D Developmental Practices	N/A
NR Not Recommended Practices	• this approach is a not recommended practice when there are insufficient hardwood stems in the pre-harvest stand to meet compositional objectives

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Silvicultural System: Clearcut Harvest Method: Conventional Clearcut (cont.)

	Comments
Considerations for Implementation	• large clearcut openings may increase the possibility of seedling damage due to frost, seedbed temperature extremes, and desiccation (Dey and MacDonald 2001) • protection and promotion of the conifer component is critical to the success of this treatment in meeting mixedwood objectives; artificial regeneration of conifers by planting is generally required • mortality of white spruce will be rapid when transmitted light is below 10% (Leiffers *et al.* 2002); > 25% of full sunlight may be required for good long-term survival and response to release of shade-tolerant boreal conifers (Greene *et al.* 2002, Ruel *et al.* 2002a) • free-to-grow standards for spruce growing under aspen canopies must consider changes in light availability as the aspen stand develops (Comeau 2001, Leiffers *et al.* 2002); light transmission below developing aspen stands may be as low as 4% 15 to 25 years after stand initiation, but increases thereafter (Pinno *et al.* 2001, Leiffers *et al.* 2002) • birch sprouting undergoes an approximately linear decline with age, and may be effectively limited after the parent trees reach 70 years of age (Zasada *et al.* 1992) • birch regeneration by seed is suitable only on coarse and medium broad soil groups in northwest ecoregions and on the coarse broad soil group in northeast ecoregions • when clearcutting in strips, the orientation and windfirmness of the leave strips must be considered (refer to Wind Damage, Section IV) • strip width should be based on the moisture limitations of the site; drier conditions may require narrower strips (Groot *et al.* 2001)
Opportunities	• spruce regeneration may occur in the pre-harvest stand as advance growth; desirable advance growth may be protected by modifying logging techniques (Groot *et al.* 2001) • this harvest method may be used to establish patchy spatial mixtures (i.e. mosaics of conifer and hardwood patches) within a single cohort, mixed species stand • emulates the light regime and other microclimatic conditions associated with a stand-replacing disturbance, such as fire
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Silvicultural System: Clearcut	Harvest Method: Clearcut with Standards
	Comments
Overview	• this is a harvest method specifically proposed to manage aspen regeneration in aspen dominated or aspen leading mixedwood conditions; although untested, it may present a useful approach that should be evaluated and monitored in boreal Ontario conditions (residual stems and snags left to meet NDPE guidelines do not fall under the provisions of this fact sheet)
Promotion of Hardwood/Conifer	• this method is proposed as an alternative to other forms of clearcutting where the objective is to reduce aspen suckering; live aspen stems are left uncut throughout the stand and the live shoots provide auxin to the root system which suppresses root suckering • it is based on the biology of aspen root suckering, attempting to reduce the proliferation of aspen root suckers that occur after clearcutting, the majority of which are eventually lost as a result of waves of self thinning in the developing stand; the reduced number of suckers directs a higher percentage of site resources to the stem growth of potential crop trees (Ruark 1990); the technique may also facilitate the introduction of a conifer component into the stand
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• the suggested procedure is (Ruark 1990): - manage aspen as a two-aged stand - harvest the original even-age aspen stand leaving 20 to 25 well-distributed aspen trees/ha after harvest - this should result in reduced, but acceptable, levels of aspen root suckering compared to conventional clearcutting; a uniform spatial distribution of regeneration, with few open gaps, is desired to promote self-pruning - at final harvest, stems from both cohorts may be selected for removal • reduced levels of aspen suckering may facilitate the introduction of a conifer component to the stand
NR Not Recommended Practices	• this is a specific method designed to exploit the biological controls of aspen root suckering and is proposed for composition types with an adequate abundance and distribution of aspen

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Silvicultural System: Clearcut	**Harvest Method: Clearcut with Standards (cont.)**	
	Comments	
Considerations for Implementation	• this method was proposed for aspen in the north central United States (Ruark 1990) • since only a few scattered trees are left after harvest, temperature and light conditions necessary to promote root suckering in aspen should not be substantially less favourable than for aspen regenerating in open areas (Ruark 1990); heavy accumulations of slash and debris after harvest will discourage aspen suckering (Peterson and Peterson 1995) • artificial regeneration and a rigorous tending schedule will likely be required to maintain the conifer component needed to achieve an aspen leading or aspen dominated future stand condition	
Opportunities	• this method is operationally simple and cost effective • loss of volume by reserving some trees from harvest may be compensated for by an increase in sawlog quality material in subsequent rotations • emulates the light regime and other microclimatic conditions associated with a stand-replacing disturbance such as blowdown, with scattered live residuals	
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Silvicultural System: Clearcut   Harvest Method: Seed Tree

	Comments
Overview	• use of this harvest method for the regeneration of white spruce, black spruce, and white birch on mixedwood sites is developmental • selection of sufficient quality seed trees, provision of adequate receptive seedbeds, and consideration of effective seeding distances are key to the success of this method (Smith 1986)
Promotion of Conifer	• this method may be implemented to regenerate white spruce and black spruce by natural seeding • vegetation management strategies will be critical to success on competitive boreal mixedwood sites
Promotion of Hardwood	• this method may be implemented to regenerate white birch by natural seeding • birch seeding is most successful on low competition sites (Peterson *et al.* 1997), and may be promoted under appropriate conditions on coarse and medium broad soil groups in northwest ecoregions and on the coarse broad soil group in northeast ecoregions • site preparation (scarification) is nearly always necessary to regenerate birch by seed (Peterson *et al.* 1997) • provides full sunlight which favours shade-intolerant species (Dey and MacDonald 2001)
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• white spruce seed trees: 5 to 12 well-spaced, fully crowned, high-quality seed trees/ha have been suggested (Lyon and Robinson 1977) • black spruce seed trees: groups of high-quality seed trees that are a minimum of 10 to 15 m in diameter, with an intergroup spacing of approximately 90 m, have been suggested; groups of seed trees are left because single black spruce trees are often quickly lost to windthrow (Groot *et al.* 2001) • white birch seed trees: 7 to 12 high-quality sawlog sized seed trees/ha have been suggested (Perala and Alm 1990); this harvest method is only proposed for birch on coarse and medium broad soil groups in the northwest ecoregions and only for the coarse broad soil group in the northeast ecoregions • for all species, suitable seedbed conditions are critical to success (see Natural Seeding [page 41] and Direct Seeding [page 49] fact sheets for additional information)
NR Not Recommended Practices	• not a suitable method for aspen regeneration due to the short period of viability of aspen seed (Navratil 1991) and rigorous seedbed requirements (Brinkman and Roe 1975, Davidson *et al.* 1988) • natural seeding success for conifers is low on aspen dominated sites

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Silvicultural System: Clearcut Harvest Method: Seed Tree (cont.)

	Comments
Considerations for Implementation	• adequate distribution and abundance of receptive seedbeds required; site preparation and tending are often required; site preparation should coincide with seed years • supplemental regeneration (e.g. fill planting) may be required to meet compositional requirements of the desired future stand condition • success of this method for white spruce is uncertain due to relatively poor seedbed conditions and high competition levels on mixedwood sites, and infrequency of seed crops (Groot *et al.* 2001) • best seedbeds for white spruce are mineral soil and rotten wood (Groot *et al.* 2001); best results for natural white spruce seeding reported on deep well drained till loams and on moist lacustrine or alluvial sands; best results are likely on fresh sites (McCulligh and Towill 1994) • on upland sites, best black spruce seedbeds occur at the mineral soil/humus interface (Fleming and Mossa 1995); of the boreal mixedwood sites, this method is best suited for black spruce on moist, medium to coarse textured soils (Groot *et al.* 2001) • best birch seedbeds are exposed mineral soil or mixed mineral soil and organic layers (Peterson *et al.* 1997) • on boreal mixedwood sites, receptive seedbeds and young germinants may potentially be smothered by hardwood litter (OMNR 1997c)
Opportunities	• emulates the light regime and other microclimatic conditions associated with a stand-replacing disturbance, such as fire, with scattered live residual trees
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Silvicultural System: Clearcut Harvest Method: Two-stage

	Comments
Overview	• two-stage harvesting is implemented to permit harvest of the overstorey while protecting windfirm advance growth (10 to 15 cm in diameter) from harvesting damage (Navratil *et al.* 1994, Lieffers *et al.* 1996b, MacDonald 1996)
Promotion of Conifer	• this harvest method is specifically designed to release large windfirm understorey spruce (advance growth – natural or planted in origin) that is developing under a hardwood or conifer overstorey (Navratil *et al.* 1994, Lieffers *et al.* 1996b, MacDonald 1996) • promotes conifers mid-tolerant and tolerant of shade that were developing in the understorey
Promotion of Hardwood	• when the overstorey is removed, shade-intolerant hardwood trees may establish in openings between the conifer advance growth (MacDonald 1996, Navratil 1996)
CR Conditionally Recommended Practices	• require that sufficient good quality advance regeneration of the desired species, density, and distribution be identified prior to overstorey harvest • require that windthrow risk is confirmed to be below critical threshholds (see Wind Damage, Section IV); if the risk is high, the canopy may be removed in two, or more harvests (Navratil *et al.* 1994) • require that careful logging techniques, including pre-harvest block layout, be used to protect advance growth during overstorey removal (see Logging Methods, page 37)
D Developmental Practices	• this approach may be applied to a distinctly two-tiered stand, resulting in an even-aged, post-harvest stand structure • this method is designed to promote a softwood dominated or softwood leading mixedwood stand condition • there should be a high stocking to conifers in the understorey so that, once the overstorey is removed, this regenerating layer quickly and fully occupies the site • the spruce understorey is protected during overstorey removal, although larger spruce (where present) may be eligible for harvest; overstorey removal by strip or patch cutting minimizes damage to the understorey (Andison and Kimmins 1999) • after overstorey removal, hardwoods can regenerate in openings between conifer advance growth to create a mixed stand; the conifer component may be supplemented by planting or it may seed in from adjacent seed sources or from seed trees left during the initial harvest (Navratil *et al.* 1994) • when aspen is the major component of the overstorey, a typical harvest sequence may be (after MacDonald 1996, Navratil 1996): - hardwood overstorey removed in a first harvest at approximately 60 years (30 to 80 years) - conifer advance growth > 10 cm dbh is protected during this harvest - all conifers > 25 cm dbh are eligible for removal during this first harvest - after overstorey removal, hardwoods may regenerate naturally in available openings among the released conifers, forming a new mixed stand

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Silvicultural System: Clearcut   Harvest Method: Two-stage (cont.)

	Comments
NR Not Recommended Practices	• this harvest method is not recommended for promoting most hardwood dominated or hardwood leading composition types • this harvest method is not recommended when balsam fir comprises the majority of the understorey advance growth; the regeneration of balsam fir is not a common forest management objective in Ontario due to its susceptibility to spruce budworm and stem and root rots (Groot *et al.* 2001) • canopy conditions at the gap dynamics stage generally not suited for this method
Considerations for Implementation	• this system may not be appropriate in Ontario where mixedwoods do not often have a distinct two-tiered structure, and where balsam fir often forms a large component of advance growth in the understorey (Wedeles *et al.* 1995, Jeglum 1996) • harvesting in the winter will reduce the risk of compaction and rutting of the fine soils on which these stands commonly occur (Pulkki 1996) • this method may increase harvesting costs for the first cut; requires greater skill in harvesting the stand to prevent excessive damage to the advance regeneration • this method requires the maintenance of access to facilitate multiple entries into the stand • this method may result in increased risk of windthrow of the released conifer understorey (refer to Wind Damage, Section IV); the canopy may be removed in two or more harvests when a more gradual opening of the canopy is required (Navratil *et al.* 1994)
Opportunities	• just prior to harvest (10 to 20 years), mature aspen stands that have adequate light transmission to the understorey may be underplanted to provide sufficient stocking of advance white spruce in the understorey; the planted spruce would then be tall enough to be seen and protected during subsequent harvest (Lieffers *et al.* 1996b); there are indications, however, that light transmission levels under certain conditions in eastern Canada may be less than in western Canada where these techniques were applied (Greene *et al.* 2002) • for successful underplanting, > 25% of full sunlight is required (and must be maintained) at seedling or sapling height (Greene *et al.* 2002); shading by both the overstorey tree canopy and understorey vegetation must be taken into account • where appropriate conditions exist, the two-stage harvest method is an effective way to increase growth of spruce while obtaining revenue from the aspen overstorey (Steneker 1963, 1967, Lees 1966, 1970, Johnson 1986, Yang 1989, 1991, Yang and Bella 1994); aspen is harvested at its biological rotation to maximize volume and quality of the harvested material (Lees 1966, Yang 1989, 1991, Navratil 1996) • emulates the light regime and other microclimatic conditions associated with a stand-replacing disturbance, such as blowdown
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Silvicultural System: Shelterwood Harvest Method: Uniform/Strip

	Comments
Overview	• natural or artificial regeneration is secured under the shelter of residual trees • "shelter" from a uniform shelterwood is provided by an overstorey canopy; shelter from a strip shelterwood may be provided by an overstorey canopy or by trees on the edges of narrow strips • selection of the spatial pattern (uniform, strip, group) for shelterwood cuts will be determined by stand conditions and operability considerations • site preparation of the seedbed and control of competing vegetation are usually required (Dey and MacDonald 2001)
Promotion of Conifer	• uniform and strip shelterwoods may be used to promote the regeneration of white spruce by seed (Wedeles *et al.* 1995, Cameron *et al.* 1999) • where reliance is placed on natural regeneration of conifers from seed, sufficient acceptable seed trees in the overstorey and adequate distribution of receptive seedbeds are required; site preparation to prepare receptive seedbeds and tending of developing regeneration is generally required
Promotion of Hardwood	• shading from overstorey or adjacent standing trees is generally not suitable for aspen regeneration • this method has been used successfully to promote the regeneration of white birch by seed (Perala and Alm 1990) • white birch seeding is most successful on low competition sites (Peterson *et al.* 1997) • regeneration of white birch from seed requires site preparation to provide sufficient mineral soil or mixed mineral soil/organic seedbeds
CR Conditionally Recommended Practices	• this method may be promoted for white birch under appropriate conditions on coarse and medium broad soil groups in northwest ecoregions and on the coarse broad soil group in northeast ecoregions
D Developmental Practices	• suggestions for white spruce regeneration from seed (after Groot *et al.* 2001): - sufficient white spruce seed trees are required in the canopy - preparatory cut should reduce basal area to a range of 9 to 14 m^2/ha, leaving mainly white spruce and eliminating aspen stems - must provide sufficient amount and distribution of receptive seedbeds; best seedbeds are mineral soil and rotten wood - site preparation normally required, and should coincide with seed years - shelter from the overstorey helps protect white spruce seedlings from frost damage - final overstorey removal should be scheduled as a winter cut after the establishment of sufficient two- and three-year-old white spruce seedlings - release of the seedlings from competing vegetation will normally be required • mature and overmature stands, with moderate to low stocking and emergent white spruce, are likely good candidates for this approach, since trees are more windfirm (Wedeles *et al.* 1995)

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Silvicultural System: Shelterwood Harvest Method: Uniform/Strip (cont.)

	Comments
D Developmental Practices (cont.)	• suggestions for white birch regeneration from seed (Peterson *et al.* 1997): - moderate shade should be provided at first; once birch is established, light availability should be increased through vegetation control and removal of the residual overstorey - moderate shade arising from dense grass and/or herbs should be avoided, owing to competition for soil moisture - disturbances that maximize mineral soil exposure promote successful birch seeding; disturbance from logging alone may result in only spotty distribution of birch seedlings • birch may benefit more when shelter is provided by narrow strips since less precipitation would be intercepted than when a tree canopy is directly overhead (Perala and Alm 1990) • birch regeneration from seed is only promoted on coarse and medium broad soil groups in northwest ecoregions, and only on the coarse broad soil group in northeast ecoregions
NR Not Recommended Practices	• uniform shelterwoods are generally not used for black spruce; black spruce is susceptible to windthrow after thinning of closed stands (OMNR 1997c) • shade from residual trees discourages aspen root suckering by reducing soil temperature (Peterson and Peterson 1995, MacDonald 2000) • overstorey conditions are generally not appropriate for implementing this method at the gap dynamics stage
Considerations for Implementation	• this method requires maintenance of access to facilitate multiple entries into the stand • stands should be assessed using the slenderness coefficient and other criteria to determine their susceptibility to windthrow (refer to Wind Damage, Section IV) • care should be taken to ensure that harvesting does not result in high-grading of the stand for the most marketable species and stems • **light levels** typically range from 20 to 60% of full sunlight in the understorey of shelterwoods (Dey and MacDonald 2001) **White spruce** • mortality of white spruce will be rapid when transmitted light is below 10% (Lieffers *et al.* 2002); > 25% of full sunlight may be required for good long-term survival and response to release of shade-tolerant boreal conifers (Ruel *et al.* 2000a, Greene *et al.* 2002) • there is often little increase in white spruce height growth above 40% light (Lieffers and Stadt 1994), although this is not always the case (Groot 1999); in contrast, maximum diameter growth consistently requires higher light levels (Lieffers *et al.* 2002) • reducing overstorey basal areas below 9 m^2/ha, or 30% of crown cover does not tend to result in continued increases in white spruce height growth (Dey and MacDonald 2001) • site preparation, or other techniques, may be required to control balsam fir (Wedeles *et al.* 1995) • supplemental regeneration may be required to meet the compositional requirements of the desired future stand condition

(Continued on next page)

Silvicultural System: Shelterwood Harvest Method: Uniform/Strip (cont.)

	Comments
Considerations for Implementation (cont.)	**White birch** • for the first three to five years following germination, partial shade (about 50% of full sunlight) may benefit the height growth of white birch; thereafter, full sunlight is needed for maximum height growth (Dey and MacDonald 2001) • to achieve good wind dispersal of white birch seed, it is suggested that only 20 to 40% of crown cover be left after harvest, leaving at least 10 to 12 birch seed trees/ha dispersed throughout the canopy (Perala and Alm 1989, Perala and Alm 1990); site preparation in conjunction with shelterwood harvest should be timed to coincide with seed years • retention of even light shelterwood overstories (e.g. about 9 m^2/ha) for extended periods reduces survival and growth of white birch (Dey and MadDonald 2001) • shelterwoods may assist birch where it has difficulty regenerating because of aggressive aspen root suckering or frequent summer droughts (Perala and Alm 1989, Perala and Alm 1990)
Opportunities	• relative to clearcuts, shelterwoods improve conditions for germinants/seedlings by providing higher humidity, cooler maximum and warmer minimum temperatures, and reduced occurrence and severity of frost (Groot *et al.* 1997); this method may be used to protect seedlings from frost and desiccation • moderate to heavy overstories can lessen competition from aspen and other shade-intolerant hardwood trees, and some woody shrubs, grasses, and herbs (Bell 1991, Lieffers and Stadt 1994, Groot *et al.* 1997, MacDonald 2000); provides relatively effective control of shade-intolerant competitors such as fireweed and Canada blue-joint (Lieffers and Stadt 1994), but less effective for controlling more shade-tolerant competitors such as beaked hazel and mountain maple (Groot *et al.* 1997) • leaving more than 50% overstorey basal area reduces the development of red raspberry, while reducing basal area to levels below 16 m^2/ha can cause dramatic increases to raspberry abundance (Dey and MacDonald 2001) • the uniform shelterwood system has been used successfully with site preparation (scarification) to naturally regenerate white spruce in the prairies (Lees 1963, 1964, 1970, Jarvis 1966, Waldron and Kolabinski 1994, Bella and Gal 1995, Ball and Walker 1995, 1997) • this method has been considered for mid-rotation stands of black spruce that are less susceptible to windthrow (Groot *et al.* 2001) • this method may be used in combination with protection of advance growth and/or artificial regeneration and tending methods (Groot 1999, Man and Lieffers 1999); when using advance growth, careful logging methods and techniques must be used to protect the advance growth during overstorey harvest cuts • uniform shelterwood initially emulates the light regime and other microclimatic conditions associated with a widespread, low-severity, non-stand-replacing fire; insect, and disease outbreak; or wind, snow, or ice damage; strip shelterwood emulates a similar localized disturbance
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Silvicultural System: Shelterwood Harvest Method: Group

	Comments
Overview	• natural or artificial regeneration is secured under the shelter of residual trees • group shelterwood may be implemented in a manner similar to a uniform shelterwood (using shelter from the overstorey), but in a pattern of expanding groups or patches; alternatively, each group could be regenerated using shelter and seed sources provided by adjacent groups • selection of the spatial pattern for shelterwood cuts (uniform, strip, or group) will be determined by stand conditions and operability considerations • site preparation of the seedbed and control of competing vegetation are usually required (Dey and MacDonald 2001)
Promotion of Conifer	• where reliance is placed on natural regeneration of conifers from seed, sufficient acceptable seed trees and adequate distribution of receptive seedbeds are required; site preparation to prepare receptive seedbeds and tending of developing regeneration is generally required; site preparation should coincide with seed years
Promotion of Hardwood	• shading from overstorey or adjacent standing trees is generally not suitable for aspen regeneration • white birch seeding is most successful on low competition sites (Peterson *et al.* 1997), and may be promoted under appropriate conditions on coarse and medium broad soil groups in northwest ecoregions and on the coarse broad soil group in northeast ecoregions • regeneration of white birch from seed requires preparation of sufficient mineral soil or mixed mineral soil/organic seedbeds
CR Conditionally Recommended Practices	• birch regeneration from seed is only promoted on coarse and medium broad soil groups in northwest ecoregions, and only on the coarse broad soil group in northeast ecoregions
D Developmental Practices	• when using this method, groups should be marked prior to harvest, taking into account regeneration requirements of the desired species. • suggestions for white spruce regeneration from seed (Groot *et al.* 2001): - sufficient white spruce seed trees are required in the canopy or in adjacent groups - preparatory cut should reduce basal area to a range of 9 to 14 m^2/ha, leaving mainly white spruce and eliminating aspen stems - must provide sufficient amount and distribution of receptive seedbeds; best seedbeds are mineral soil and rotten wood - site preparation normally required, and should coincide with seed years - shelter from the overstorey helps protect white spruce seedlings from frost - final overstorey removal should be scheduled as a winter cut after the establishment of sufficient two- or three-year old seedlings - release of the seedlings from competing vegetation will normally be required • suggestions for white birch regeneration from seed (Peterson *et al.* 1997): - moderate shade should be provided at first; once birch is established, light availability should be increased through vegetation control and removal of the residual overstorey - moderate shade arising from dense grass and/or herbs should be avoided, owing to competition for soil moisture

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Silvicultural System: Shelterwood Harvest Method: Group (cont.)	
	Comments
D Developmental Practices (cont.)	- disturbances that maximize mineral soil exposure promote successful birch seeding; disturbance from logging alone may result in only spotty distribution of birch seedlings
NR Not Recommended Practices	• shade from residual trees discourages aspen root suckering by reducing soil temperature (Peterson and Peterson 1995)
Considerations for Implementation	• this method requires maintenance of access to facilitate multiple entries into the stand • careful logging techniques should be used during overstorey removal (see Logging Methods, page 37) • requires the seed source for the desired species be in proximity to the group that is being regenerated and protected, or artificial regeneration is required • care should be taken to ensure that harvesting does not result in high-grading of the stand for the most marketable species and stems • shelterwood openings of approximately one tree height in diameter, and larger, have resulted in aspen sucker densities that were no different than densities occurring in clearcuts (Groot *et al.* 1997, Kabzems 1998), but subsequent survival and growth of aspen may be reduced • overstorey shelter generally protects seedlings from frost (Carlson and Groot 1997, Man and Lieffers 1999), but on some sites, openings created by group shelterwood can potentially become frost pockets • supplemental regeneration may be required to meet compositional requirements of the desired future stand condition • **light levels** typically range from 20 to 60% of full sunlight in the understorey of shelterwoods (Dey and MacDonald 2001) • mortality of white spruce will be rapid when transmitted light is below 10% (Lieffers *et al.* 2002); > 25% of full sunlight may be required for good long-term survival and response to release of shade-tolerant boreal conifers (Ruel *et al.* 2000a, Greene *et al.* 2002) • there is often little increase in white spruce height growth above 40% light (Lieffers and Stadt 1994), although this is not always the case (Groot 1999); in contrast, maximum diameter growth consistently requires higher light levels (Lieffers *et al.* 2002) • reducing overstorey basal areas below 9 m^2/ha, or 30% of crown cover, does not tend to result in continued increases in white spruce height growth (Dey and MacDonald 2001)
Opportunities	• this method may provide one of the best opportunities to promote an irregular stand structure and natural regeneration of white spruce, which tends to be patchy within a stand • may be used in combination with protection of advance growth and artificial regeneration methods; when using advance growth, logging systems and techniques must be selected that protect advance growth during overstorey harvest cuts • initially emulates the light regime and other microclimatic conditions in a localized, low-severity, non-stand-replacing fire; insect and disease outbreaks; or wind, snow, or ice damage
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Silvicultural System: Selection   Harvest Method: Individual

	Comments
Overview	• this method may be used to create an irregular stand structure, emulating the gap dynamics stage, and to promote shade-tolerant species (e.g. balsam fir)
Promotion of Conifer	• natural regeneration from seed may be used in combination with protection of advance growth and artificial regeneration methods; when using advance growth, logging systems and techniques must be selected that protect advance growth during overstorey harvest cuts
Promotion of Hardwood	N/A
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• the promotion of balsam fir regeneration is not a common forest management objective in Ontario due to its susceptibility to spruce budworm and to stem and root rots (Groot *et al.* 2001) • however, the suggested procedure for using this method to regenerate balsam fir is (Groot *et al.* 2001): - select good quality, windfirm stands that have mixed age and size classes - cuttings may be made at intervals of 5 to 20 years, but removals should not exceed 30% of the stand basal area - cutting may be made to a residual basal area of approximately 18 m^2/ha, removing a range of tree sizes and ages; select largest trees as well as closely spaced and poor quality stems
NR Not Recommended Practices	• this approach is not suitable for regenerating aspen and birch (Dey and MacDonald 2001) • generally not an acceptable method of promoting spruce; the proportion of spruce regenerating by this method would depend on the size of the openings resulting from single-tree removal, the nature and intensity of competition from other species (that would help determine the sufficiency of light required for survival and growth), the availability of spruce seed, and the availability of receptive seedbeds • this is not a recommended treatment for earlier stand development stages • in boreal conditions, stands should not be kept in a selection system indefinitely due to risks associated with repeated partial harvest (see Section III)
Considerations for Implementation	• this method requires maintenance of access to facilitate multiple entries into the stand • a major disadvantage of this method is that it increases the stand's susceptibility to spruce budworm infestation • understorey **light levels** may be only slightly higher using this method than in undisturbed stands; shade intolerant and intermediate species may germinate in heavy shade, but understorey light is usually insufficient for their long-term survival (Dey and MacDonald 2001) • the growth of shade-tolerant species is also reduced by low light, but they have a higher capacity to survive and respond to release after long periods of suppression (Dey and MacDonald 2001); however, for fir and spruce, > 25% of full sunlight may still be required to ensure good long-term survival and response to release (Ruel *et al.* 2000a, Greene *et al.* 2002)

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Silvicultural System: Selection Harvest Method: Individual (cont.)

	Comments	
Opportunities	• emulates the light regime and other microclimatic conditions associated with small canopy gaps formed by individual tree mortality due to senescence, insects and diseases, or wind, snow, or ice damage	
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Silvicultural System: Selection Harvest Method: Group

	Comments
Overview	• group selection cuts have an arbitrary maximum width of opening that is equal to twice the height of mature trees; larger cuts are considered patch clearcuts (Smith *et al.* 1987)
Promotion of Conifer or Hardwood	• the group selection method has not previously been used to regenerate boreal tree species in Ontario (Dey and MacDonald 2001) • however, depending on the size of opening (which can range up to two tree heights in diameter), and position within an opening, it is possible to accommodate the ecological requirements of almost any tree species, from shade tolerants to intolerants (Dey and MacDonald 2001) • centres of the largest openings created by group selection may have environmental conditions similar to clearcuts until adjacent crowns encroach in the opening or regeneration develops (Dey and MacDonald 2001)
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• regeneration gaps should be marked prior to harvest; all trees within the designated gap must be removed (except good quality, desirable advance growth, where present) to provide a gap size suitable for regeneration of the desired species **Spruce** • for natural regeneration of spruce by seed, sufficient numbers of suitable seed trees must be in the proximity of the gap or artificial regeneration will be required; seedbed receptivity and the nature and intensity of competition must be considered • natural seeding may be used in conjunction with the protection of advance growth and/or artificial regeneration **White birch** • openings with a diameter of one-quarter to one-half of the surrounding tree heights are suggested as the minimum for establishing birch because of rapid canopy closure (Peterson *et al.* 1997)
NR Not Recommended Practices	• the smaller gaps created by group selection harvesting are not suitable for aspen regeneration; shading of the forest floor by trees surrounding the gap can reduce soil temperature and, therefore, aspen root suckering; subsequent survival of aspen suckers would also be poor owing to light constraints • this method is not recommended when balsam fir comprises the majority of the understorey advance growth; the regeneration of balsam fir is not a common forest management objective due to its susceptibility to spruce budworm and stem and root rots (Groot *et al.* 2001) • this is not a recommended treatment for earlier stand development stages • in boreal conditions, stands should not be kept in a selection system indefinitely due to risks associated with repeated partial harvest (see Section III)

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Silvicultural System: Selection	Harvest Method: Group (cont.)
	Comments
Considerations for Implementation	• this method requires maintenance of access to facilitate multiple entries into the stand • regeneration objectives for the harvested gaps should be clearly defined prior to harvest; the seed source for the desired species must be in proximity to the gap (in the overstorey or in adjacent seed sources), or artificial regeneration is required • all trees within a marked gap are harvested (except good quality advance growth), to create gaps of the desired size and environmental conditions • care should be taken to ensure that harvesting does not result in high-grading a stand for the most marketable species and stems • careful logging techniques should be used to minimize damage to desired residual stems (see Logging Methods, page 37) Light Regime • the size, shape, and orientation of the opening and the position of the tree within the opening (e.g. edge, centre) affect the intensity and duration of light that a seedling receives (Dey and MacDonald 2001) • if several species are regenerating in gaps, there is a strong tendency for the more shade-tolerant ones to predominate; cuttings must provide for the environmental conditions for the desired species and, if necessary, follow-up tending and release may be required (Smith 1986) • smaller openings may be used to establish seedlings because competition and seedbed desiccation are reduced in smaller gaps; however, smaller gaps may close quickly depending on the species and vigour of adjacent trees and the size of advance growth within the gap (Dey and MacDonald 2001) • shade generally protects seedlings from frost (Groot and Carlson 1996, Man and Lieffers 1999), but on some sites, openings created by group selection harvest may potentially become frost pockets
Opportunities	• may be used to promote or maintain an uneven-aged conifer mixedwood condition in the later stage of stand development (i.e. gap dynamics stage) • when groups are harvested, light removal cuts may occur outside the group to remove poor quality stems, undesirable species, or smaller stems in clumps that hinder the growth of future crop trees • the multiple, frequent harvests that characterize this method, emulate the light regime and other microclimatic conditions associated with small-scale, localized disturbances that occur in older stands as a result of tree mortality in groups, from factors such as windthrow, insect and disease damage, and wind, snow, or ice damage
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Logging Methods

	Comments
Overview	• three general categories of logging methods are: full-tree , tree-length, and shortwood (cut-to-length) logging (see Section III) • in addition to the economics of harvest, selection of a logging method has particular impact on the following aspects of boreal mixedwood management: - protection of advance growth and residual trees - accumulation of slash - the number and distribution of cones left on site - disturbance of organic layers
Promotion of Conifer or Hardwood	N/A
CR Conditionally Recommended Practices	• careful logging practices are required to minimize logging damage; these include providing operator training to minimize damage when working in partial harvest situations; pre-planning harvest layout; selecting and marking skid trails to minimize site disturbance and protect residual trees and/or advance growth; requiring felling and skidding equipment to use the same trails; marking rub posts for use along skid trails and at tight corners; and using directional felling • require that logging only be permitted on frozen ground or with low-impact equipment when there is potential for rutting and compaction (OMNR 1997c); potential for site damage is particularly high on saturated, fine-textured and moist mineral soils
D Developmental Practices	N/A
NR Not Recommended Practices	• full-tree logging is not recommended for any harvest methods or thinning treatments that leave a partial overstorey or when protection of advance growth is required; in these cases, the risk of unacceptable levels of damage to residual stems will be high
Considerations for Implementation	• all logging methods may result in damage to residuals; 10 to 20% of stems damaged is not uncommon for full-tree logging (Pulkki 1996); cut-to-length may result in damage as low as 2% • as part of the silvicultural prescription, objectives relating to acceptable levels of harvesting damage should be determined • cut-to-length is the most suitable logging method for shelterwood and selection harvest methods, small patch harvesting, and thinning • in a two-stage harvesting operation, feller-bunchers working with grapple skidders caused minimal damage to residuals with operator-controlled felling direction and bunching location (Navratil *et al.* 1994); protection of understorey may increase with the use of feller bunchers and single-grip harvesters

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Logging Methods (cont.)

	Comments
Considerations for Implementation (cont.)	• careful logging practices include: - providing operator training for working in partial harvest situations - pre-planning harvest layout; selecting and marking skid trails to minimize site disturbance and protect residuals and/or advance growth - operating felling and skidding equipment on the same trails - delimbing stems before skidding - using "rub trees" along skid trails and at tight corners - where possible, avoiding harvest in spring when the opportunity for bark damage is greatest - using directional felling - using the main-line and winch (where applicable) to reduce the amount of travel of harvesting equipment • tree-length and cut-to-length logging will result in higher slash loadings on site than will full-tree logging: - increased shading of the forest floor from logging debris will reduce soil temperatures and may reduce the amount of aspen root suckering - increased slash loading will reduce the distribution and abundance of plantable spots and receptive seedbeds • windrowed slash from single-grip harvesters may result in uneven distribution of aspen suckers and a reduction of available seedbed
Opportunities	(based on Kenney and Towill 1999) • season of harvest must be considered in selecting a logging method to meet mixedwood objectives; for example, logging on frozen ground reduces the amount of site and soil disturbance • accumulations of slash, and the amount and distribution of plantable spots and receptive seedbeds, may be modified using appropriate site preparation treatments • some slash may benefit tree establishment by modifying the microclimate and providing some seed • full-tree logging is suitable for stands with smaller trees due to the multiple tree-handling ability of feller-bunchers
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Regeneration Type: Natural	Regeneration Method: Advance Growth
	Comments
Overview	• advance growth is composed of tree species mid-tolerant to tolerant of shade, such as white spruce, black spruce, and balsam fir (Weetman and Vyse 1990)
Promotion of Conifer	• advance conifer growth may be protected during harvesting operations to contribute conifer stocking to the developing stand
Promotion of Hardwood	• advance growth is not a viable technique for regenerating shade-intolerant hardwoods
CR Conditionally Recommended Practices	• where most advance growth is large and near-merchantable (10 to 15 cm dbh), advance growth must be below a critical slenderness coefficient to lower the probability of windthrow and top breakage following overstorey removal (see Wind Damage, Section IV) • layer-origin black spruce is acceptable as potential advance growth only on moist mineral soils • careful logging practices for the protection of advance growth are required
D Developmental Practices	N/A
NR Not Recommended Practices	• full-tree logging is not recommended when harvesting to protect advance growth
Considerations for Implementation	• white spruce advance growth is rarely abundant in Ontario (Groot *et al.* 2001) • black spruce advance growth is not abundant and is very variable within and between sites (Walsh and Wickware 1991, Arnup 1996a, b, c); on upland boreal mixedwood sites, black spruce advance growth is generally only sufficiently abundant to be considered supplementary, rather than the primary source of regeneration (Walsh and Wickware 1991) • presence and abundance of seed origin black and white spruce advance growth is limited due to the lack of spruce seed source and sufficient quality and quantity of receptive seedbeds (Groot *et al.* 2001) • balsam fir advance growth is generally abundant, but longevity and growth is affected by spruce budworm population levels • advance growth should be evaluated to assess its ability to respond to release and to determine its acceptability as the new crop • ability of balsam fir and black spruce advance growth to respond to improved light conditions can be related to pre-harvest live crown ratio and the percentage of stem surface area wounded or damaged during harvest (Ruel and Doucet 1998, Ruel *et al.* 2000a) • survival and growth of advance regeneration following overstorey removal is favoured on moist sites where partial canopy removal has occurred (Kneeshaw and Bergeron 1996) • ability of advance growth to positively respond to changing light and other microclimatic conditions is delayed on dry sites following full canopy removal; survival and growth of balsam fir advance growth is particularly adversely affected by prolonged periods of drought • advance growth may not be a reliable source of regeneration on clearcuts where silvicultural practices can result in damage and seedling mortality may increase from sudden exposure to full light conditions (Ferguson 1984, Ruel *et al.* 2000a)

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Regeneration Type: Natural	Regeneration Method: Advance Growth (cont.)
	Comments
Considerations for Implementation (cont.)	• harvesting can result in significant damage and reduction in densities of advance growth (Walsh and Wickware 1991), although 80% of pre-harvest stocking of black spruce advance growth can survive after winter harvesting with careful logging (Groot 1995) • damage to advance growth can be reduced during harvest through use of high floatation tires, winter logging, and careful directional felling and skidding with spaced skid trails (Walsh and Wickware 1991) • when advance growth is small (e.g. 0.5 to 2.5 m in height), a minimum pre-harvest seedling density of 18,000 stems/ha is suggested to achieve 40% stocking (based upon a 4 m^2 assessment plot) (Greene *et al.* 2000, 2002)
Opportunities	• black spruce advance growth densities ranging from 5,000 to 15,000 stems/ha have been documented for some sites in northwestern Ontario, with the majority of advance growth less than 0.5 m in height (Buse and Farnsworth 1995) • due to less than recommended pre-harvest black spruce advance growth stocking levels on most boreal mixedwood sites, some form of supplementary regeneration (e.g. fill planting or natural seeding where the opportunity exists) will likely be required • advance spruce that is a minimum of 2.5 to 3.5 m in height may be successfully released by overstorey removal (Johnson 1986, Yang 1989, Bell 1991); spruce of shorter stature can be susceptible to overtopping by regenerating hardwood trees and/or woody shrubs following overstorey removal
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<table>
<tr><th colspan="2">Regeneration Type: Natural Regeneration Method: Seed</th></tr>
<tr><td></td><td>Comments</td></tr>
<tr><td>Overview</td><td>• use of this treatment for the regeneration of white spruce, black spruce, and white birch on boreal mixedwood sites is developmental</td></tr>
<tr><td>Promotion of Conifer</td><td>• clearcut with seed trees, clearcut with pre-harvest understorey site preparation, shelterwoods, and group selection harvests may be used to regenerate white and black spruce by natural seeding</td></tr>
<tr><td>Promotion of Hardwood</td><td>• natural seeding may be used to promote white birch
• birch regeneration is most successful on low competition sites (Peterson <i>et al.</i> 1997), and may be promoted under appropriate conditions on coarse and medium broad soil groups in northwest ecoregions and on the coarse broad soil group in northeast ecoregions</td></tr>
<tr><td>CR Conditionally Recommended Practices</td><td>N/A</td></tr>
<tr><td>D Developmental Practices</td><td>• sufficient distribution of receptive seedbeds is critical; when preparing seedbeds prior to harvest, site preparation should result in 35% coverage of receptive seedbeds (refer to autecology tables in Section VII for appropriate seedbeds); site preparation should be timed with a seed year (Greene <i>et al.</i> 2002)
• conifer seeding results must be closely monitored to identify vegetation management requirements, including protecting conifer seedlings from smothering by leaf litter
• using pre-harvest site preparation, basal areas of white spruce seed trees required in the canopy to obtain various stocking levels have been proposed for Alberta boreal mixedwood sites, as follows (Greene <i>et al.</i> 2000, 2002):
<table>
<tr><th rowspan="2">Residual Stand Characteristics</th><th colspan="3">Stocking Levels</th></tr>
<tr><th>Minimum 0–30%</th><th>Moderate (30–50%)</th><th>Full (100%)</th></tr>
<tr><td>Basal area (BA) of seed trees (m^2/ha)</td><td>1</td><td>2</td><td>6.6</td></tr>
<tr><td>Density of seed trees/ha (#trees > 40 cm dbh)</td><td>12</td><td>24</td><td>75</td></tr>
</table>
• for additional recommendations on natural seeding, see Seed Tree (page 24), Shelterwood (page 28), and Selection (page 33) harvest methods fact sheets</td></tr>
<tr><td>NR Not Recommended Practices</td><td>• aspen regeneration by seed is highly variable due to a short period of seed viability (Navratil 1991) and rigorous seedbed requirements (Brinkman and Roe 1975, Davidson <i>et al.</i> 1988)
• potential for recruitment of white and black spruce from seed is low for aspen dominated, white birch dominated, aspen leading, and white birch leading mixedwoods
• regeneration of balsam fir not a common management objective due to its susceptibility to eastern spruce budworm and stem and root rots (Groot <i>et al.</i> 2001)</td></tr>
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Regeneration Type: Natural Regeneration Method: Seed (cont.)

	Comments
Considerations for Implementation	• seed-tree harvest should be delayed for a number of years to increase seeding success; seeding should be completed within four years of site preparation (Greene *et al.* 2000), because seedbed quality declines rapidly as vegetation colonizes the site and organic matter begins to accumulate; on boreal mixedwood sites, receptive seedbeds may quickly become covered with hardwood litter (OMNR 1997c)
Opportunities	• understorey scarification could be conducted prior to final overstorey harvest to secure natural regeneration of spruce from seed; harvest of seed trees occurs after seed release
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Regeneration Type: Natural Regeneration Method: Vegetative/Coppice

	Comments
Overview	• vegetative reproduction may result in rapid development of hardwood species
Promotion of Conifer	N/A
Promotion of Hardwood	• after cutting parent trees, trembling aspen regenerates rapidly from root suckers and white birch regenerates from stump sprouts
CR Conditionally Recommended Practices	• requires a sufficient distribution of white birch and/or aspen stems to meet hardwood compositional requirements for the desired future stand condition • require 100 to 120 aspen stems/ha (Davidson *et al.* 1988)(or 20% basal area of aspen) well distributed throughout the pre-harvest stand to provide for adequate vegetative reproduction of aspen to meet aspen dominated or aspen leading future stand conditions • to secure adequate aspen vegetative reproduction (and prevent site damage), harvesting may not occur when the ground is subject to compaction or rutting (a particular concern on fine and moist mineral soils) (Perala 1981, Bates *et al.* 1993); winter logging can be used to reduce soil compaction and mechanical damage to root systems
D Developmental Practices	N/A
NR Not Recommended Practices	N/A
Considerations for Implementation	**Aspen** • the average area covered by individual trembling aspen clones in northwestern Ontario is 0.12 ha, but on occasion may exceed 2.0 ha (Kemperman 1977) • most aspen suckers are located within 5 m of the nearest bole, with dispersion declining rather abruptly within another 10 m (Greene *et al.* 1999) • most aspen suckers originate from roots 0.8 to 1.8 cm in diameter and within 8 cm of the mineral soil surface • soil temperature is the most important environmental factor controlling sucker formation; aspen suckering is inhibited by root zone temperatures lower than 15° C, and is optimal between approximately 20 and 30° C (Maini and Horton 1966, Maini 1967) • heavy accumulations of slash and debris after harvest will discourage aspen suckering (Peterson and Peterson 1995) • forest floor organic layers greater than 15 cm will generally require site preparation to facilitate mineral soil exposure or mineral soil/organic layer mixing to ensure adequate warming of the rooting zone for aspen (Perala 1991a) • most suckers are produced in the first growing season following disturbance (Sandberg 1951); scarification after aspen suckering has commenced will result in reduced height growth of the replacement suckers (Weingartner 1980)

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Regeneration Type: Natural Regeneration Method: Vegetative/Coppice (cont.)

	Comments
Considerations for Implementation (cont.)	• vigorous aspen sucker production can be encouraged by complete removal of the overstorey to eliminate apical dominance and promote soil warming (Horton and Maini 1964, H.W. Anderson *et al.* 2001); however, minimum canopy openings 20 to 25 m in diameter may also support aspen (Paré and Bergeron 1995, Carlson and Groot 1997, Kneeshaw and Bergeron 1998, Cumming *et al.* 2000, Kelly *et al.* 2001) • harvesting aspen in the dormant season results in maximum aspen suckering during the next growing season since carbohydrate reserves are at their highest during dormancy (Schier and Zasada 1973); however, after two or three years, stem density is the same on summer-logged as on winter-logged sites (Bella and DeFranceschi 1972, Perala 1981, Bates *et al.* 1993) • stand age does not affect the ability of aspen to sucker, provided that the stand is not subject to break-up or decay (Steneker 1976, Zasada *et al.* 1992, Lavertu *et al.* 1994, Frelich and Reich 1995); overmature stands may have inadequate suckering ability due to shrinking root systems or thick forest humus layers which prevent sucker production due to low soil temperatures (Perala 1991a) **Birch** • birch sprouting undergoes an approximately linear decline with age, and may be effectively limited after parent trees reach 70 years of age (Zasada *et al.* 1992) • sprouting in white birch is encouraged by cutting stumps low to the ground (< 30 cm) and in the spring; the most vigorous sprouts are produced from small to medium sized stems (Perala 1974a)
Opportunities	• vegetative regeneration of trembling aspen and white birch can provide for rapid stand establishment, often at a low cost (usually just the cost of logging) • vegetative reproduction of white birch from stump sprouts may result in several stems that will require pre-commercial thinning in order to yield a suitable stem free of defect and sweep
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Regeneration Type: Artificial Regeneration Method: Pre-harvest Underplant

	Comments
Overview	• generally involves planting of conifers prior to final harvest
Promotion of Conifer	• underplanting is typically done 20 to 40 years prior to overstorey harvest, creating a distinct two-tiered stand structure • underplanting promotes a future conifer dominated or conifer leading stand condition
Promotion of Hardwood	N/A
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• adequate light levels in the regeneration zone is key for success of this treatment; 25% of full sunlight is required (and must be maintained) at seedling or sapling height (Greene *et al.* 2002), with shading by both the overstorey tree canopy and understorey vegetation being taken into account • maintaining > 25% of full sunlight is necessary for good survival and eventual response to release of understorey shade-tolerant conifers (Greene *et al.* 2002) • there are indications that light transmission levels through mature aspen stands under certain conditions in eastern Canada may be less than in western Canada where underplanting has been implemented (Greene *et al.* 2002, and refer to summary of light levels by jurisdiction in Table 2 of Section IV) - although data are sparse, light levels measured thus far beneath mature closed canopy aspen stands in Ontario appear to be marginal to insufficient for underplanting in the absence of partial canopy removal (see Table 2, Section IV) - information is lacking on light conditions beneath mature closed canopies of white birch in Ontario; but information from other jurisdictions suggests light conditions may be insufficient for underplanting in the absence of partial canopy removal (see Table 2, Section IV) • in British Columbia, adequate light levels for underplanting have been met in 40- to 60-year-old aspen dominated or aspen leading boreal mixedwood stands with less than 1,200 stems/ha (35 m^2/ha) (Delong *et al.* 2000) • underplanting may be carried out in conjunction with a shelterwood harvest (partial canopy removal) where overstorey trees are left • juvenile aspen stands that are to be underplanted may be spaced to appropriate densities to allow for adequate light transmission (Coopersmith and Hall 1999, Lieffers *et al.* 2002, Comeau 2001) • light transmission levels may be greatly reduced under intact juvenile aspen stands; the lowest period of light transmission in developing aspen stands appears to occur between the ages of 15 and 25 years and may reach levels as low as 4% of full sunlight (Pinno *et al.* 2001, Lieffers *et al.* 2002) • at least 50% canopy cover should be maintained to reduce competition from understorey non-crop vegetation (Greene *et al.* 2000) • understorey site preparation or cleaning may be required to control non-crop vegetation, particularly where competition from beaked hazel, mountain maple, or Canada blue-joint is anticipated

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Regeneration Type: Artificial Regeneration Method: Pre-harvest Underplant (cont.)

	Comments
D Development Practices (cont.)	• spacing of seedlings when underplanting can be fixed or random, but seedlings should be at least 1 m from live dominant hardwood stems (Delong *et al.* 2000) • planting should be scheduled for early spring when moisture is highest and prior to bud break of overstorey hardwoods (Green *et al.* 2000) • careful logging practices should be used when harvesting the overstorey
NR Not Recommended Practices	• full-tree logging is not recommended when attempting to protect underplanted seedlings
Considerations for Implementation	• snowshoe hares can cause heavy browse damage to underplanted seedlings, especially if seedlings are nutrient loaded; to minimize hare damage: - underplanting should ideally occur after peaks in hare populations and on sites that do not offer suitable habitat - underplant in the interior of large, contiguous, mature aspen stands • access trails should be left unplanted if tending or other treatments will require repeat entries to the stand • two-stage harvesting of merchantable hardwood overstorey can be initiated when underplanted conifers are large enough to withstand post-harvest competition and mechanical damage
Opportunities	• potential for underplanting conifers in intact hardwood dominated or hardwood leading boreal mixedwood stands has been demonstrated in various jurisdictions under suitable light conditions (Kabzems and Lousier 1992, Dyck 1994, Tanner *et al.* 1996, Comeau *et al.* 1998, 1999, MacDonald 2000, Stewart *et al.* 2000, Delong et al. 2000, Sherman *et al.*, in prep. a, b) • underplanting conifers in conifer leading or conifer dominated boreal mixedwood stands may also be an option (Man and Lieffers 1999, Lieffers *et al.* 1999), as long as light requirements are met • underplanting may also be carried out in conjunction with a shelterwood harvest; stands could be spaced to create light levels suitable for underplanting • underplanting can emulate natural succession by accelerating natural stand development from a hardwood condition to softwood dominated or softwood leading condition
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Regeneration Type: Artificial	**Regeneration Method: Post-harvest Plant**
	Comments
Overview	• with appropriate vegetation management, this is a reliable technique for introducing conifer to a mixedwood stand
Promotion of Conifer	• post-harvest planting may be used to establish the coniferous component of mixedwood stands; this is a reliable method for achieving conifer dominated or conifer leading stand conditions • tending is generally required to maintain the survival and growth of conifers on boreal mixedwood sites
Promotion of Hardwood	N/A
CR Conditionally Recommended Practices	• planting must be monitored and appropriate vegetation management techniques applied to protect conifer regeneration while maintaining the hardwood component of the mixedwood stand
D Developmental Practices	N/A
NR Not Recommended Practices	• when aspen dominated and birch dominated future stand conditions are the objective, post-harvest planting is not recommended since broadcast tending methods (which is damaging to the hardwood component) would be required (cluster planting is the conditionally recommended regeneration method in these situations)
Considerations for Implementation	• future stand composition will depend on tree species planted, tending, ingress, and the presence of advance growth • site type, site preparation method, stock types, and the type of planting tool can influence the number and distribution of suitable planting spots (McClain and Willcocks 1988) • current site preparation practices to promote black and white spruce on conventional clearcut boreal mixedwood sites usually involve post-harvest organic matter removal using some form of mechanical site preparation combined with chemical site preparation for vegetation control (Sutherland and Foreman 2000)
Opportunities	• fill planting can be used to supplement natural regeneration from seed or advance growth
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Regeneration Type: Artificial Regeneration Method: Cluster Planting

	Comments
Overview	• this method is used to introduce the conifer component of a mixedwood stand usually following conventional clearcutting or uniform shelterwood harvests
Promotion of Conifer	• future stand composition can be manipulated by varying the percentage of the area occupied by the conifer planting • planting densities for clusters and the inter-cluster spacing must be consistent with future stand objectives (e.g. planting densities would be greater to achieve a conifer leading future stand condition than to achieve an aspen leading stand condition)
Promotion of Hardwood	• an even-aged hardwood condition is promoted in the intervening spaces between the clusters of planted conifers (BCMoF 2000)
CR Conditionally Recommended Practices	• clusters must be monitored and vegetation management techniques applied to keep conifer regeneration free of overtopping and lateral competition; a competition-free zone should be maintained around each cluster
D Developmental Practices	N/A
NR Not Recommended Practices	• this technique is not recommended when a conifer dominated future stand condition is the objective (post-harvest planting throughout the stand (not just clusters) is conditionally recommended to meet objectives in these circumstances)
Considerations for Implementation	• clusters have been established using white spruce trees spaced 1 to 1.4 m apart; other species may be considered for cluster planting if environmental conditions are suitable for their survival and growth • future stand yields will be influenced by initial number of trees per cluster, inter-tree spacing, and associated individual tree growth response (Terlesk and McConchie 1988)
Opportunities	• this method can be used to create patchy mosaics of conifers and hardwoods
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Regeneration Type: Artificial	**Regeneration Method: Direct Seed**
	Comments
Overview	• involves the manual or mechanical sowing of seed • successful direct seeding depends on proper site selection, adequate site preparation, and good seed distribution
Promotion of Conifer	• direct seeding may be used to establish spruce, but results are unreliable in boreal mixedwood conditions
Promotion of Hardwood	• direct seeding may be used to promote white birch • birch regeneration is most successful on low competition sites (Peterson *et al.* 1997), and may be promoted under appropriate conditions on coarse and medium broad soil groups in northwest ecoregions and on the coarse broad soil group in northeast ecoregions
CR Conditionally Recommended Practices	• precision seeding of spruce is conditionally recommended in spruce dominated mixedwoods for the establishment of a softwood dominated or softwood leading condition; assessments are to begin within two years of seeding to determine seeding success and evaluate and schedule vegetation management requirements
D Developmental Practices	• white birch direct seeding on coarse or medium soil groups in northwest ecoregions, and on the coarse soil group in northeast ecoregions, is a developmental practice • recommendations for white birch direct seeding (Perala and Alm 1990): - precision seeding (rather than broadcast seeding) is preferred - seeding should be on scarified seed spots; best germination occurs on shaded mineral soil seedbeds (Peterson *et al.* 1997) - seed may be sown in fall or spring; seeding may be more successful if the seedbed is allowed to stabilize before sowing - seed may be protected with shelter cones to improve germination • shading improves establishment of birch from seed; once birch is established, light availability should be increased to improved seedling growth (Peterson *et al.* 1997)
NR Not Recommended Practices	• white spruce and black spruce direct seeding on upland boreal mixedwood sites is not recommended; aerial seeding of white spruce has been attempted in other jurisdictions but found to be unreliable (Waldron 1974); seedbed requirements for successful black spruce establishment are very precise and aerial seeding is also unreliable; precision seeding improves opportunities for matching seed to a receptive seedbed, but intense competition and smothering of seedlings with hardwood litter on mixedwood sites contribute to the poor success of this treatment

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Regeneration Type: Artificial   Regeneration Method: Direct Seed (cont.)

	Comments
Considerations for Implementation	• direct seeding is less reliable than natural seeding because seed application, and subsequent germination and establishment, must be completed under the conditions of one growing season • delays between seedbed creation and seeding may result in loss of receptive seedbeds as a result of covering by hardwood litter • seeding must be followed by early vegetation management to control herbaceous and graminoid vegetation (Bell *et al.* 1992) • continuous furrow scarification is the preferred site preparation method for spot seeding of upland sites because it promotes ingress of naturals, facilitates microsite selection, and contributes to higher worker productivity (Adams *et al.* 2001) • precision seeding of black spruce: - results in more efficient use of seed than broadcast application (Dominy and Wood 1986, Adams 1995) - provides better control of seedling density and spacing than broadcast seeding (Van Damme *et al.* 1988, Corbett 1992) - must be conducted in the spring; the suggested rate is 15 seeds per seed spot (Adams *et al.* 2001) • boreal mixedwood ecosites 25 (Northwest Region) and 5f and 5m (Northeast Region) are suggested as "best bets" for successful seeding of black spruce
Opportunities	N/A
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Site Preparation Method: Manual/Motor-manual

	Comments
Overview	• this method involves manually preparing sites (e.g. using hand-held equipment) before or after harvest • manual techniques include boot screefing, mattocks, and grub hoes for preparing planting sites, and axes, brush hooks, shears, and machetes for removing woody shrubs • motor-manual techniques include motor-driven scarifiers attached to brushsaws for preparing planting sites and brushsaws and chainsaws for removing woody shrubs • manual and motor-manual techniques maximize protection of advance growth, minimize damage to residual stems, and minimize unwanted disturbance of the organic layers and the soil seed bank
Promotion of Conifer	• conifer planting or seeding spots may be prepared by manual or motor-manual means • techniques used to remove competing brush and hardwood stems prior to regeneration are similar to manual cleaning treatments
Promotion of Hardwood	• manual and motor-manual techniques provide an opportunity for protecting hardwood crop trees while preparing the site for additional regeneration treatments
CR Conditionally Recommended Practices	• this method is only recommended for reducing the litter layer or removing slash to prepare planting spots or receptive seedbeds for precision seeding; if extensive brush competition occurs on a boreal mixedwood site, this method alone will not result in successful seeding or planting
D Developmental Practices	N/A
NR Not Recommended Practices	• these techniques are not recommended when regenerating by natural seeding since the required seedbed conditions (distribution and abundance) are better obtained using mechanical site preparation techniques • these techniques are not recommended for controlling brush when vigorous vegetative reproduction of hardwoods is being promoted
Considerations for Implementation	• boot screefing is most often used where the forest humus layer is 5 to 10 cm in thickness • site conditions, including the type and abundance of ground vegetation, determine the efficacy of brushsaw-mounted scarifiers; see Cormier (1989) and Maxwell (1989) for an evaluation of several motor-manual scarification devices
Opportunities	• manual and motor-manual techniques may be combined with chemical treatments; cut hardwood stems may be treated with liquid herbicide applied with an applicator attached to a brush cutter; when combining these treatments with chemical application refer to product labels for information on herbicide efficacy, species sensitivity, and recommended timing of application • manual trampling or binding of mountain maple appears to be an effective technique for controlling its regrowth, since trampling does not promote re-sprouting from basal sprouts (Aubin and Messier 1999, Kneeshaw *et al.* 1999) • these techniques may be appropriate for use in partial harvest situations to undertake "spot" treatments and to minimize damage to residual stems or protect advance growth
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Site Preparation Method: Mechanical and Chemi-mechanical

	Comments
Overview	• mechanical site preparation implements may create screefed, inverted, mounded, trenched, or mixed soil profiles • herbicides may be applied in conjunction with mechanical site preparation (chemi-mechanical) to delay re-establishment of competitive species • in addition to general considerations used in planning mechanical site preparation (e.g. desired microsite, terrain and slope limitations, rockiness and stoniness), certain factors have particular emphasis in boreal mixedwood management: - amount and distribution of logging debris and stumps - frequency and size of residual stems in partial canopy removal systems - protection of advance growth - amount of brush cover (see Considerations for Implementation) • for a thorough review of mechanical site preparation treatments in Ontario, see Sutherland and Foreman (1995), and Ryans and Sutherland (2001)
Promotion of Conifer	• mechanical site preparation is generally required to provide sufficient well-distributed seedbeds when regenerating white spruce or black spruce by seed (OMNR 1997c) • site preparation is also generally required before planting conifers on productive boreal mixedwood sites • chemicals may be applied in bands when site preparing areas for conifer establishment, which allows flexibility when protecting advance growth or desirable hardwoods
Promotion of Hardwood	• mechanical site preparation is almost always required to provide sufficient well-distributed seedbeds when regenerating white birch by seed (Perala and Alm 1990, Peterson *et al.* 1997) • site preparation (scarification) may also be used to redistribute logging debris and improve conditions for aspen suckering; however, if applied after suckering, scarification will result in a reduction in the dominant height of aspen (Weingartner 1980) • chemicals must be selectively applied if the hardwood component is to be protected
CR Conditionally Recommended Practices	• the following conditions must be met when using mechanical or chemi-mechanical site preparation for natural regeneration of white spruce (Zasada 1972): - site preparation must be completed no later than mid-August during a good to excellent seed year - site preparation must provide for an average of 5 to 10% mineral soil exposure well distributed over 55 to 65% of the harvest area - site preparation must result in scarified patches that are a minimum of 1 to 1.5 m in the smallest dimension • mechanical site preparation to stimulate vegetative reproduction of aspen must be applied prior to suckering following harvest (Weingartner 1980) • appropriate manoeuvrable equipment must be used when site preparing in the vicinity of residual stems or advance growth that is to be protected

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Site Preparation Method: Mechanical and Chemi-mechanical (cont.)

	Comments
CR Conditionally Recommended Practices (cont.)	• mineral soil exposure must be minimized on clays to reduce the incidence of baking and/or frost heaving, and to prevent increased competition from non-crop vegetation on a mixed mineral/ organic site • chemi-mechanical site preparation treatments must be compatible with the hardwood objective for the desired future stand condition; these treatments have the potential to damage white birch or trembling aspen crop trees • must refer to product labels for information on herbicide efficacy, species sensitivity, and recommended timing of application when using any method that incorporates the use of chemicals
D Developmental Practices	• pre-harvest site preparation (used in preparation for planting or seeding) is a developmental treatment • pre-harvest site preparation using blades has been done previously on boreal mixedwood sites in Ontario for the creation of white spruce seedbeds; the results are inconclusive given that this also disturbs the underlying aspen root mat, stimulating the production of suckers which quickly occupy the available growing space • spot screefing treatments are currently being applied throughout western Canada in partial harvest and understorey situations in boreal mixedwood conditions using small excavators and skid-steer loader prime movers (D. Sidders, pers. comm.) • exposure of mineral soil while ensuring the removal of herbaceous and graminoid non-crop vegetation is essential to the satisfactory natural regeneration of white spruce (Packee 1990)
NR Not Recommended Practices	• site preparation on saturated, fine-textured soils is not recommended; site preparation should not be conducted under any conditions that result in soil compaction or rutting
Considerations for Implementation	• high volumes of post-harvest downed woody debris have occurred in mixedwood stands (Sutherland and Foreman 1995), generally as a result of poor utilization or high levels of cull • mechanical equipment best suited for heavy slash conditions are plows, brush blades, or rakes (Coates and Haeussler 1989) • powered disc trenchers and patch scarifiers have produced mixed results in heavy slash; however, plows may be attached to the front of the prime mover to improve results (Coates and Haeussler 1989) • winter logging operations tend to create high stumps; stumps from white birch clumps may also create significant obstacles to the operation of the prime mover and the site preparation equipment (Ryans 1989) • site preparation implements pulled by a skidder are generally preferable when stumps are high or frequent; skidders have a higher clearance than tractors and their articulated steering allows them to "duck walk" off obstacles (Ryans 1989) • ability to avoid residual trees and advance growth is dependent on prime mover manoeuvrability and length of prime mover/implement combination (Ryans 1989)

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Site Preparation Method: Mechanical and Chemi-mechanical (cont.)

	Comments
Considerations for Implementation (cont.)	• for similar sized machines, skidders generally have a shorter turning radius than tractors due to their articulated steering; skidders also have the ability to reduce "off tracking", a situation where the rear of the machine does not cover the same path as the front (Ryans 1989); both factors would favour protection of residuals and advance growth by increasing manoeuvrability and reducing the percentage of the area traversed by equipment • heavy brush cover (especially green brush) may impede the effectiveness of site preparation equipment in creating desired microsites and may reduce treatment coverage and machine productivity • for a review of the impact of various soil profiles created by different site preparation implements on crop and non-crop vegetation, see McMinn and Hedin (1990), Sutherland and Foreman (1995), and Ryans and Sutherland (2001) • on productive sites, non-crop vegetation may quickly be established on raised berms; sides of berms are prone to drying out (Bell *et al.* 1992) • on fine-textured soils, minimal mineral soil exposure is desirable due to the risk of seedling mortality from frost heaving or drying out (Walstad and Kuch 1987, Sutherland and Foreman 1995); mixing may be a better option (McMinn and Hedin 1990) • mixing may encourage re-sprouting of competing vegetation (Sutherland and Foreman 1995); leaching of nutrients from the site may be reduced by spot mixing (McMinn and Hedin 1990) • for evaluations of specific mechanical site preparation implements in dealing with these and other conditions, refer to Smith (1979), Coates and Haeussler (1989), and Ryans and Sutherland (2001)
Opportunities	• this type of site preparation may be carried out either before or after harvest • site preparation with a shear blade has been effective for the establishment of planted white spruce on conventional clearcuts in Ontario (Sutton and Weldon 1995) • planting white spruce on inverted mineral mounds has been successful in British Columbia; seedlings demonstrate the same long-term mechanical stability as seedlings planted without site preparation (Heineman *et al.* 1999). • planting white spruce on mounds with thick mineral soil caps, particularly where screefing occurs before mounding, may greatly reduce the negative impacts of Canada blue-joint on white spruce establishment (Landhäusser and Lieffers 1999) • blading with small bulldozers has been effective for the establishment of underplanted white spruce in partially harvested mixedwoods in Ontario (Wedeles *et al.* 1995) and Alberta (Man and Lieffers 1999, Stewart *et al.* 2000) • mixing with a mixing head has been used to successfully establish underplanted white spruce in boreal mixedwood shelterwood cuttings in Alberta (Man and Leiffers 1999); this treatment is being investigated for use in shelterwood, patch cut, and clearcuts in Ontario (Sutherland 1996) • when herbicide is being applied as part of the site preparation treatment, it may be sprayed as a liquid (e.g. using a scarifier-sprayer) between or directly into scarified patches, or distributed as a granular formulation (e.g. using a centrifugal-type device) over patches or trenches (Desrochers and Dunnigan 1991)
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Site Preparation Method: Chemical

	Comments
Overview	• chemical site preparation involves broadcast aerial applications or broadcast or selective ground-based applications of herbicides prior to the regeneration treatment for the purpose of controlling competing vegetation (Campbell *et al.* 2001)
Promotion of Conifer	• for black and white spruce, chemical site preparation (before planting) can be more effective in controlling competing non-crop species than chemical cleaning one year after planting (Wood and von Althen 1993); where chemical site preparation is used, crop trees are not injured by direct contact with herbicide and do not have to endure competition during the first growing season following outplanting
Promotion of Hardwood	• where chemicals are applied, intolerant hardwood regeneration will be discouraged
CR Conditionally Recommended Practices	• require appropriate manoeuvrable equipment when conducting ground-based chemical site preparation to ensure protection of desired residual stems or advance growth • chemical site preparation treatments must be compatible with the hardwood objective for the desired future stand condition; if not properly implemented, chemical site preparation may damage white birch or aspen crop trees • must refer to product labels for information on efficacy, species sensitivity, and recommended timing and methods of application when using herbicides
D Developmental Practices	• pre-harvest chemical site preparation is a developmental treatment; the ability to conduct the treatment effectively without detrimental impact on crop trees must be determined
NR Not Recommended Practices	• chemical site preparation does not provide the receptive seedbed conditions required for seeding success • chemical site preparation on saturated, fine-textured soils using ground-based equipment is not recommended; site preparation should not be conducted under any conditions that result in soil compaction or rutting • chemical site preparation is not recommended for the promotion of white birch or trembling aspen regeneration due to the susceptiblity of these species to damage or mortality from herbicides
Considerations for Implementation	• herbicides commonly used in the boreal mixedwood forests of Ontario are glyphosate, hexazinone, triclopyr, and simazine; the susceptibility of crop trees and target species to these herbicides is reviewed by McLaughlan *et al.* (1996); suggested application times for glyphosate and hexazinone are outlined by Carruthers and Towill (1988) • 2,4-D is discouraged for chemical site preparation on upland boreal mixedwood sites due to the promotion of hardwood re-sprouting and re-suckering from affected stems (Carruthers and Towill 1988) • chemical site preparation using glyphosate should be scheduled two years after logging or mechanical site preparation to ensure effective control of those species that reproduce vegetatively, from wind-borne seed, or from the soil seed bank, after disturbance • ground application equipment such as the cluster nozzle sprayers and mist blowers may be used to apply herbicides

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Site Preparation Method: Chemical (cont.)

	Comments
Considerations for Implementation (cont.)	• access and operability are not limiting factors to aerial application of herbicides for site preparation • effective site preparation may be obtained using only herbicides, when the density of slash and logging residue from the previous harvest is light and is well distributed across the site, or woody non-crop vegetation is sparse enough to permit natural or artificial regeneration to be secured at a reasonable cost (Sutton 1985) • winter logging operations tend to create high stumps; stumps from white birch clumps may also create significant obstacles to the operation of the prime mover and ground chemical site preparation equipment (Ryans 1989) • ground-based chemical site preparation is usually limited to situations where vegetation is less than 2 m in height to ensure satisfactory efficacy (Bell *et al.* 1992) • efficacy of chemical site preparation is significantly affected by the susceptibility of the target non-crop, competing vegetation (McMinn and Hedin 1990) and the timing of application • woody species that reproduce from the soil seed bank may be promoted by chemical site preparation, which exposes the duff layer to full sunlight and precipitation (Mallik *et al.* 1996) • chemical site preparation may leave a residue of standing dead or dying vegetation that may impede planting or seeding and may also shelter animal pests and allow them to proliferate
Opportunities	• chemical site preparation may leave the forest floor essentially undisturbed, and, therefore, conditions are less favourable for the germination of wind-borne seeds and seeds in the soil seed bank (Bell 1991); soil disturbance is minimized and inherent site productivity is maintained (Walstad and Kuch 1987) • chemical site preparation may be used to control current non-crop vegetation and/or future non-crop vegetation predicted to arise through vegetative reproduction or from seed (Campbell *et al.* 2001) • chemical site preparation is useful in unstocked or understocked portions of plantations, or in natural stands where the application of prescribed burning or mechanical site preparation would cause unacceptable damage to residual overerstorey stems, advance growth, or previously established regeneration (Boyd 1982, Sutton 1985)
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Site Preparation Method: Prescribed Burning

	Comments
Overview	• prescribed burning (fire) may be used to prepare seedbeds or planting spots for conifers, to reduce slash and organic layers, to stimulate hardwood regeneration, or to control competing vegetation (Wiltshire and Archibald 1998)
Promotion of Conifer	• post-harvest prescribed burning may be as effective or more effective than post-harvest mechanical site preparation in improving conditions for conifer establishment and growth (McRae 1985a, Arnup 1989, Ballard and Hawkes 1989, Wiltshire and Archibald 1998) • late summer burns are advised for preparing boreal mixedwood sites for conifer regeneration; late summer applications generally result in deeper burns which reduce the vegetative reproduction of hardwoods and shrubs, and decrease the soil seed bank of other competitive species (Wiltshire and Archibald 1998) • high-severity prescribed burns may damage aspen root systems (Perala 1974b) and reduce the vigour of aspen suckers (Rowe 1953)
Promotion of Hardwood	• medium severity prescribed fires are suitable for regenerating aspen, especially when carried out immediately following harvest and prior to initial root suckering (Peterson and Peterson 1995) • light-severity burns may not remove enough slash, ground vegetation, and organic matter to promote adequate aspen suckering (Horton and Hopkins 1965) • light or moderate burns will encourage white birch regeneration by stimulating root collar sprouting and by preparing receptive seedbeds for the light, wind-dispersed seed of this species
CR Conditionally Recommended Practices	• requires careful consideration of fire weather indices under which prescribed burning is to be conducted on boreal mixedwood sites; indices must be sufficient for fire spread and to meet fuel consumption objectives • requires careful planning using the *Prescribed Burn Planning Manual* (OMNR 1997a)
D Developmental Practices	N/A
NR Not Recommended Practices	• the application of fire prior to harvest to prepare planting or seeding spots is a not recommended practice due to the potential damage to crop trees, loss of value, and increased risks • prescribed burning is a not recommended practice when promoting advance regeneration
Considerations for Implementation	• guidelines have been developed to predict fuel consumption and estimate fire behaviour in the mixedwood fuel complex (McRae 1980, McRae 1985b) • post-harvest prescribed burns have often been conducted on boreal mixedwood sites under fire weather indices that are too low to meet objectives of fire spread and fuel consumption (McRae 1985b) • fire prescriptions that have a fuel consumption objective that may be achieved using lower fire weather indices will increase the burn window and decrease fire control efforts (Wiltshire and Archibald 1998) • prescribed burns scheduled for early spring will permit adequate fire spread and behaviour under lower indices, since it is more difficult for the fire to spread after leaf flush (McRae 1985b, Wiltshire and Archibald 1998)

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Site Preparation Method: Prescribed Burning (cont.)

	Comments
Considerations for Implementation (cont.)	• prescribed burning as a site preparation treatment for seeding should be timed with good seed years • prescribed burning may only control competing vegetation temporarily (Methven and Murray 1974, Jeglum and Kennington 1993) • prescribed burning may be a cost-effective site preparation tool (Wiltshire and Archibald 1998)
Opportunities	• mixedwood forests are dependent upon periodic fire to maintain their health, productivity, and diversity; the use of prescribed burning reintroduces fire as a natural component of the ecosystem (Wiltshire and Archibald 1998) • prescribed burning is the best site preparation method for removing heavy accumulations of logging slash, and for reducing wild fire hazard • fire will eliminate balsam fir advance growth (McRae 1985a, Arnup 1989) • medium-severity burns are considered optimal for the removal of slash, humus, brush, residual trees, and for the promotion of aspen suckering (Horton and Hopkins 1965) • chemical pretreatments may be used to cure fuels prior to prescribed burning, thereby improving fire spread (Wiltshire and Archibald 1998) • various tools have been developed to assist with the planning of prescribed burning (Wearn *et al.* 1982, Stocks *et al.* 1990, McCarthy *et al.* 1994, McRae 1996, 1980).
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Tending/Cleaning Method: Manual and Motor-manual

	Comments
Overview	• permits a directed and "crop tree centred" approach to release individual crop trees
Promotion of Conifer	• conifer crop trees growing in mixtures may be released from unwanted competition while protecting hardwood crop trees
Promotion of Hardwood	• hardwood crop trees may be released by this method where the broadcast application of herbicides would otherwise damage or kill the hardwood component of the desired future stand condition
CR Conditionally Recommended Practices	N/A
D Developmental Practices	N/A
NR Not Recommended Practices	N/A
Considerations for Implementation	• volume growth and survival of conifers consistently increases after competition is controlled (Wagner *et al.* 1999) and in direct proportion to the degree and duration of control achieved • a key consideration of this approach is that there are sufficient stems of the desired species to meet post-treatment compositional objectives and maintain site occupancy • cutting techniques are not effective in controlling the density and abundance of herbaceous and graminoid species • sprouting in white birch, mountain maple, pin cherry, and beaked hazel can be minimized by cutting very low to the ground (< 10 cm) (Harrington 1984, Hart and Comeau 1992, Jobidon 1997) • mountain maple will re-sprout forming clumps after cutting and temporary increases in stem density are common (Harvey *et al.* 1998) • manual or motor-manual cleaning to remove trembling aspen should be undertaken in mid-summer when carbohydrate stores for sucker and sprout production are at their lowest (Bell et al. 1999) • manual or motor-manual cleaning to remove aspen should target cutting immediately below the live crown or at a height of 50 to 75 cm to reduce the potential for re-suckering or the development of shoots from dormant buds in the lower portion of the stem (Bell *et al.* 1999) • tools and techniques which result in jagged cuts produce fewer and less vigorous sprouts than the clear cut of a brush saw (Bell *et al.* 1997) • manual girdling is effective for releasing conifer crop trees from dense overstorey canopies of hardwoods • manual and motor-manual cutting are also effective for controlling the density of unwanted conifer stems (e.g. unwanted balsam fir) • cutting non-crop vegetation may do little to reduce competition for moisture and nutrients, and may even increase it, even though growing space and light availability may be improved; combined chemi-mechanical control should be considered where competition for moisture, nutrients, and growing space is of concern
Opportunities	• manual trampling or binding of mountain maple appears to be an effective technique for controlling its regrowth since trampling does not promote basal re-sprouting (Aubin and Messier 1999, Kneeshaw *et al.* 1999)
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Tending/Cleaning Method: Chemical (Direct and Broadcast)

	Comments
Overview	• involves the application of chemicals to release conifer regeneration • chemicals may be applied in a broadcast application (aerially or on the ground) or in a selective application (i.e. band or spot application)
Promotion of Conifer	• herbicides are typically used to release conifer regeneration from surrounding non-crop vegetation • chemical cleaning is used to promote the conifer component of a developing mixedwood stand, which is generally difficult to establish
Promotion of Hardwood	• selective applications may be used to protect hardwood crop trees while releasing conifers
CR Conditionally Recommended Practices	• chemical cleaning must be compatible with the hardwood objective of the mixedwood stand; if not properly implemented (e.g. selective application), chemical treatments may damage desired white birch or aspen regeneration • must refer to product labels for information on herbicide efficacy, species sensitivity, and recommended timing of application when using any method that incorporates the use of chemicals; herbicides vary in their efficacy and ability to control different species of competing vegetation • chemical cleaning with ground-based equipment is not recommended on saturated, fine-textured soils; ground-based equipment should not be used under any conditions that result in soil compaction or rutting
D Developmental Practices	• chemical cleaning prior to harvest is a developmental practice
NR Not Recommended Practices	• chemical cleaning is not recommended when promoting the white birch or trembling aspen component of regeneration due to the susceptibility of these species to herbicides and the high potential for damage or mortality
Considerations for Implementation	• volume growth and survival of conifers consistently increases after competition is controlled (Wagner *et al.* 1999) and in direct proportion to the degree and duration of control achieved; early chemical cleaning following establishment of the conifer component is considered biologically cost-effective (Lautenschlager and Sullivan 2002) **Broadcast Applications** • aerial or ground broadcast application of glyphosate at the stand initiation stage to release planted white and black spruce is effective at controlling the abundance and dominance of woody shrubs and herbaceous species on boreal mixedwood sites (Reynolds *et al.* 1997), while maintaining much of the stand-level plant species diversity (Biring and Hays-Byl 2001, Bell and Newmaster 1998, Lautenschlager and Sullivan 2002) • broadcast application of glyphosate is effective at controlling Canada blue-joint on boreal mixedwood sites in northern Ontario (Bell *et al.* 2000) • ground application technology such as cluster nozzle sprayers and mist blowers can be used to apply herbicides for the release of conifer beneath a partial canopy without damaging or killing hardwood stems in the overstorey (Desrochers and Dunnigan 1991)

(Continued on next page)

Tending/Cleaning Method: Chemical (Direct and Broadcast) (cont.)

	Comments
Considerations for Implementation (cont.)	**Selective Applications** • ground application of herbicides to selectively control competing vegetation around conifers may be the most desirable method of chemical cleaning in developing hardwood leading, conifer leading, or conifer dominated mixedwood stands (Bell *et al.* 1996) **Band Application** - band application of herbicides (also called "green striping") at the stand initiation stage to remove overtopping and lateral non-crop vegetation surrounding conifers can be used to favour a hardwood leading or softwood leading mixture; green striping can be carried out with broadcast aerial spraying or using backpack sprayers or "reel and hose" technology **Spot Application** - chemical cleaning involving the spot application of herbicides permits a highly selective crop tree centred approach to managing competition within and between species - backpack sprayers can be used to apply herbicide directly onto the foliage of competing woody and/or herbaceous vegetation, or onto the surface of freshly cut stumps surrounding planted seedlings; the latter is highly effective at eliminating large woody stems - backpack sprayers and spotgun applicators can be used to apply triclopyr herbicide to the basal bark of small diameter (< 15 cm) woody stems to prevent vegetative reproduction (basal sprouting and root suckering) - cut stump application of herbicides can also be accomplished using a brushsaw/cleaning saw with a herbicide applicator; the applicator applies herbicide to the lower side of the brush saw blade as it cuts the target stem - woody stems can also be targeted using the "hack and squirt" method where several cuts are made in the bark with an axe or knife followed by the application of herbicide to the exposed cambial layer - selective injection of herbicides is effective for releasing conifer crop trees from dense hardwood overstories
Opportunities	
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Additional Silvicultural Treatments at Stand Initiation: Supplemental Regeneration

	Comments
Overview	• supplemental regeneration refers to the application of one or more silvicultural treatments at the stand initiation stage to establish trees in areas of inadequate stocking to meet compositional objectives • for example, portions of an aspen dominated stand at initiation could be site prepared and planted with conifers to meet the compositional requirements of an aspen leading condition • when supplemental regeneration treatments are being applied, coding conventions (i.e. R, CR, NR, D, and X) apply as described for each of the treatments that have been selected to comprise the silvicultural treatment package
Promotion of Conifer	• for selected regeneration options, consult applicable fact sheets
Promotion of Hardwood	• for selected regeneration options, consult applicable fact sheets
CR Conditionally Recommended Practices	• for selected regeneration options, consult applicable fact sheets • implementation of treatments should not result in the loss of the spruce component of the stand
D Developmental Practices	• for selected regeneration options, consult applicable fact sheets • some compositional objectives may not be achievable from the current stand condition while maintaining site occupancy
NR Not Recommended Practices	• for selected regeneration options, consult applicable fact sheets • this is not a recommended practice when site occupancy will not be maintained to achieve compositional objectives • this method is listed as a not recommended practice when treatment is not required to meet compositional objectives (i.e. current and future stand conditions are the same)
Considerations for Implementation	• for selected regeneration options, consult applicable fact sheets
Opportunities	• for selected regeneration options, consult applicable fact sheets
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Additional Silvicultural Treatments at Stand Initiation: Reinitiate

	Comments
Overview	• reinitiate involves the application of any combination of appropriate silvicultural treatments throughout a stand at the initiation stage when the composition or condition of the stand is deemed not acceptable • reinitiate is one management option; it is considered a "retreatment" as described in the *Silvicultural Effectiveness Monitoring Manual for Ontario* (OMNR 2001c) • when reinitiating the stand, the designations (i.e. R, CR, NR, D, and X) apply as described for each of the treatments that have been selected to comprise the silviculture treatment package
Promotion of Conifer	• for selected regeneration options, consult applicable fact sheets
Promotion of Hardwood	• for selected regeneration options, consult applicable fact sheets
CR Conditionally Recommended Practices	• for selected regeneration options, consult applicable fact sheets
D Developmental Practices	• for selected regeneration options, consult applicable fact sheets
NR Not Recommended Practices	• for selected regeneration options, consult applicable fact sheets
Considerations for Implementation	• for selected regeneration options, consult applicable fact sheets
Opportunities	• for selected regeneration options, consult applicable fact sheets
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Tending/Intermediate Stand Treatment: Compositional Treatment

	Comments
Overview	• the primary objective of a compositional treatment is to change stand composition type through removal of sufficient overstorey stems (e.g. a compositional treatment could be applied to change an aspen leading mixture to a softwood leading mixture by removing some aspen stems) • this treatment may be conducted in young stands (similar to juvenile spacing or pre-commercial thinning) or older stands at the stem exclusion stage where merchantable volume may be removed (similar to commercial thinning)
Promotion of Conifer or Hardwood	• various proportions of hardwoods and/or undesirable conifers may be removed to achieve compositional objectives
CR Conditionally Recommended Practices	• when a compositional treatment is used to create a hardwood leading mixture, stocking of desirable conifers must be sufficient to ensure that site occupancy is recovered • a compositional treatment in a softwood leading or softwood dominated condition is only permitted if the spruce component of the stand is not being targeted for removal; only unwanted conifer species may be removed (e.g. balsam fir) and sufficient conifer stems must remain to provide for rapid recovery of site occupancy • compositional treatments are not permitted if, to achieve a compositional objective, an unacceptable reduction in site occupancy will occur (e.g. excessive numbers of trees are removed requiring an extended period to recover site occupancy)
D Developmental Practices	N/A
NR Not Recommended Practices	• treatment in these composition types will result in insufficient conifers in the residual stand to recover site occupancy
Considerations for Implementation	• the impact of this treatment on future stand development and site utilization is the key focus • compositional treatments should be monitored to ensure that there is not an excessive removal of stems which would result in underutilization of the site for an extended period - size of trees to be killed or removed, the impact of the treatment on the remaining stems, and the promotion of undesirable competition should be considered in selecting a method of conducting a compositional treatment - methods for conducting a compositional treatment may include cutting, girdling, or chemical treatments (see Liberation Treatment, page 67, for a description of these methods)
Opportunities	• this treatment may mimic natural successional trends by removing shade-intolerant tree species to favour more shade-tolerant tree species • undesirable shade-tolerant conifers (e.g. balsam fir) may also be targeted for removal
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Tending/Intermediate Stand Treatment: Juvenile Spacing and Pre-commercial Thinning

	Comments
Overview	• juvenile spacing occurs when the stand is still in the stand initiation stage (i.e. prior to crown closure) • pre-commercial thinning (PCT) applies after the stand has reached crown closure and entered the stem exclusion stage • the primary objective of both treatments is to remove undesirable trees to promote the growth of crop trees
Promotion of Conifer	• spacing or thinning of spruce is generally not required on naturally established upland sites, which are seldom overstocked to spruce
Promotion of Hardwood	• spacing or thinning of aspen and birch is a questionable silvicultural expenditure when fibre production is the goal because aspen and birch self-thin effectively (Peterson and Peterson 1995, Peterson *et al.* 1997). • spacing or thinning of aspen and white birch stands may be justified to improve the yield of large diameter trees or to increase crop tree value, but should be considered only for the best sites; for example, when vegetative reproduction of white birch from stump sprouts results in several stems (coppice clumps), spacing or thinning may be required to yield a suitable stem free of defect and sweep
D Conditionally Recommended Practices	• spacing or thinning of aspen is generally not required if fibre production is the goal (Peterson and Peterson 1992), because aspen self-thins very effectively (OMNR 1997c); treatments may be required to increase product value, or to reduce the time the stand will take to become merchantable
D Developmental Practices	**White Birch** • little experience with pre-commercial thinning white birch in Ontario • pre-commercial thinning may potentially have negative effects such as the delay of natural pruning, growth of large lower branches, increased taper of crop trees, and decreased total biomass yield; there are also questions about the economics of pre-commercial thinning (Peterson *et al.* 1997) • suggestions for pre-commercial thinning in pure, single-storied birch stands (Peterson *et al.* 1997, Towill 2000) are: - target density for high-quality birch stems (average 13 cm dbh) is 1,000 to 1,500 stems/ha - begin thinning at age 10 to 15 years or when the stand is 4 to 6 m in height, once dominance is well established - retain the straightest, fastest growing, and healthiest stems - thin coppice clumps to one or two stems per clump - retain the best formed, most widely spaced, low-origin (i.e. originating at ground level or no more than 15 cm above ground level), dominant or codominant sprouts with U-type connections between companion sprouts; V-type sprout connections should be treated as a single unit, either leaving or cutting both - retain sprouts on the uphill side of the stump on slopes

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Tending/Intermediate Stand Treatment: Juvenile Spacing and Pre-commercial Thinning (cont.)

	Comments
NR Not Recommended Practices	• spacing or thinning black spruce and white spruce that has been naturally established on upland sites (in softwood dominated or softwood leading composition types) is rarely required since stands are seldom overstocked
Considerations for Implementation	• both juvenile spacing and pre-commercial thinning retain the original species composition of the overstorey **Aspen** • pre-commercial thin during the dormant season to reduce the risk of damage to residual stems; wounds can provide entry points for decay (Perala 1978) • thinning by motor-manual and mechanical methods tends to be effective (OMNR 1997c, St. Amour 2000, David *et al.* 2001) • if thinning is uniform throughout the stand (i.e. where a motor-manual method is used), remove the smaller trees and leave the larger trees of greatest vigour (i.e. thinning from below) to focus on the growth potential of the best trees in the stand • for mechanical strip thinning, leave strips should not exceed 2 m in width and cut strips should not exceed 4 m (Stenecker 1976); this suggestion assumes no additional manual thinning in the leave strips • alternatively, mechanical strip thinning has been done leaving wider (5.6 m) untreated strips between cleared strips; motor-manual techniques were then used to select crop trees in the leave strips (St Amour 2000) • to promote aspen dominated stands: - initiate thinning after expression of dominance begins, which is generally from 7 to 10 years or at 5 cm dbh (Perala 1991b), but may be expressed later on cool soils in northern Ontario (Rice *et al.* 2001) - space or thin to approximately 2.5 m (1,600 stems/ha) (Steneker 1976) • Hypoxylon canker incidence is thought to be greater in thinned aspen stands (Day and Strong 1959, Anderson 1964, Anderson and Anderson 1968, Copony and Barnes 1974, Brunck and Manion 1980, Ostry *et al.* 1988); however, Pitt *et al.* (2001) did not observe any relationship between stand density and Hypoxylon incidence in young, thinned aspen stands throughout northern Ontario
Opportunities	N/A
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Tending/Intermediate Stand Treatment: Liberation Treatment

	Comments
Overview	• liberation treatment is the release of young stands, not past the sapling stage, from the competition of distinctly older, overtopping trees (Smith *et al.* 1997) • overstorey trees must be considered for treatment when they are a detriment to the continued development of the regenerating stand (e.g. excessive shading) • a liberation treatment may be conducted by cutting, girdling, or chemical treatment • a liberation treatment by cutting is similar to a removal cutting of a seed tree or shelterwood method in which overstorey trees are removed after regeneration has become established; in liberation treatments, however, the overstorey trees were not left intentionally to provide seed, or shelter, or to accumulate additional growth
Promotion of Conifer	• conifer understorey is released when the overstorey is treated
Promotion of Hardwood	N/A
CR Conditionally Recommended Practices	N/A
D Developmental Practices	N/A
NR Not Recommended Practices	• a liberation treatment is not recommended as a component of a silvicultural treatment package for the management of hardwoods
Considerations for Implementation	• selection of a liberation method (cutting, girdling, or chemical treatment) should consider the size of trees to be killed or removed, the impacts of the treatment on the regenerating stems, and the promotion of undesirable vegetative reproduction of hardwoods; the following methods may be used (after Smith *et al.* 1997): **Cutting** • provides an opportunity to capture some merchantable volume from overstorey trees • felling of large, undesirable stems without using them is the most expensive form of liberation treatment • felling should only be considered as the method of liberation when the felled trees may be removed from the stand causing minimal damage to reproduction, or when the retention of standing dead stems may constitute a safety hazard (e.g. adjacent to travel corridors)

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Tending/Intermediate Stand Treatment: Liberation Treatment (cont.)

	Comments
Considerations for Implementation (cont.)	**Girdling** • girdling should encompass the entire tree, in a wide strip, down to the sapwood • insufficient girdling may render the treatment ineffective; insufficient girdling includes not completely encircling the entire stem, using narrow girdles (such as those that result from single incisions), or making shallow girdles that leave the cambium partially intact; in those instances, the remaining cambium may have sufficient contact, or may form callous bridges across the girdle, that permit the flow of sufficient water and nutrients so that the tree is not killed • girdling may be completed with axes or chainsaws; methods should consider safety and the efficiency and effectiveness of the treatment in killing the stem • girdling may be completed by "peeling" strips of bark off the stem after making two continuous cuts around the stem of the tree; this treatment is completed in the spring when the bark is loose; 20 cm wide strips are advised to ensure that the cambium is exposed to desiccation • methods that interrupt the upward flow of stored substances from the roots result in increased suckering or sprouting in hardwood species **Chemical Treatments** • chemical treatments may be completed by stem injection or selective spray (see Chemical Tending fact sheet, page 60) • this is an effective treatment for mid-size and smaller trees, and increases worker safety relative to cutting and girdling • treatments that rely on chemical translocation should consider the seasonal variation in phloem and xylem transport • chemical treatments may be applied alone or in conjunction with girdling treatments; chemical treatments are more effective than girdling alone in preventing suckering
Opportunities	• girdling may be combined with chemical injection treatments to improve the effectiveness of the treatment
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Tending/Intermediate Stand Treatment: Commercial Thinning

	Comments
Overview	• the objective of commercial thinning is increased stem growth in the residual stems with the potential for positive financial return (Smith *et al.* 1997) • there has been some recent experience with commercial thinning in plantations in Ontario's boreal mixedwood forest
Promotion of Conifer	• commercial thinning of a black spruce stand in northeastern Quebec (Lussier 2001), and of a balsam fir stand in northwestern Ontario (Van Schip *et al.* 1990), both showed no response to thinning in the residual stands; however, Weetman *et al.* (1980), in Quebec showed promising responses for black spruce on an upland site, and little loss due to increased blowdown
Promotion of Hardwood	• results of commercial thinning in aspen in Quebec showed increased individual tree size, but decreased total volume/ha after 25 years (Doucet 2000) • commercial thinning of aspen in Minnesota is restricted to better than average sites (David *et al.* 2001)
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• commercial thinning is a developmental practice in boreal mixedwood management in Ontario for softwood pure or softwood dominated stands that have a history of density regulation; although there has been operational experience in the boreal forest, there is still a need to assess the growth response for this treatment, particularly for boreal mixedwood species; stands with a history of density regulation offer the most potential for a growth response in residual stems
NR Not Recommended Practices	• commercial thinning is a not recommended practice under other boreal mixedwood conditions (i.e. stands that are not softwood pure or softwood dominated or have no history of density regulation)
Considerations for Implementation	• commercial thinning retains the original species composition of the overstorey • intensity of thinning (amount of basal area removal) greatly affects volume production in the residual stand (Lussier 2001) • stands should be assessed using the slenderness coefficient and other criteria to determine the susceptibility to windthrow (refer to Wind Damage, Section IV) • care must be taken to protect the advance growth if it is part of the desired future stand condition • care must be taken not to cause unacceptable levels of damage to residual stems
Opportunities	• with an approved monitoring program, commercial thinning can be carried out; there is much to learn about the interaction of site, thinning intensity, type of thinning, effects of varying species compositions, and stand age at time of thinning and their impact on the duration and amount of response in the residual stand • commercial thinning emulates a non-stand-replacing disturbance such as a low-severity, understorey fire, insect or disease damage, or moderate wind, snow, or ice damage
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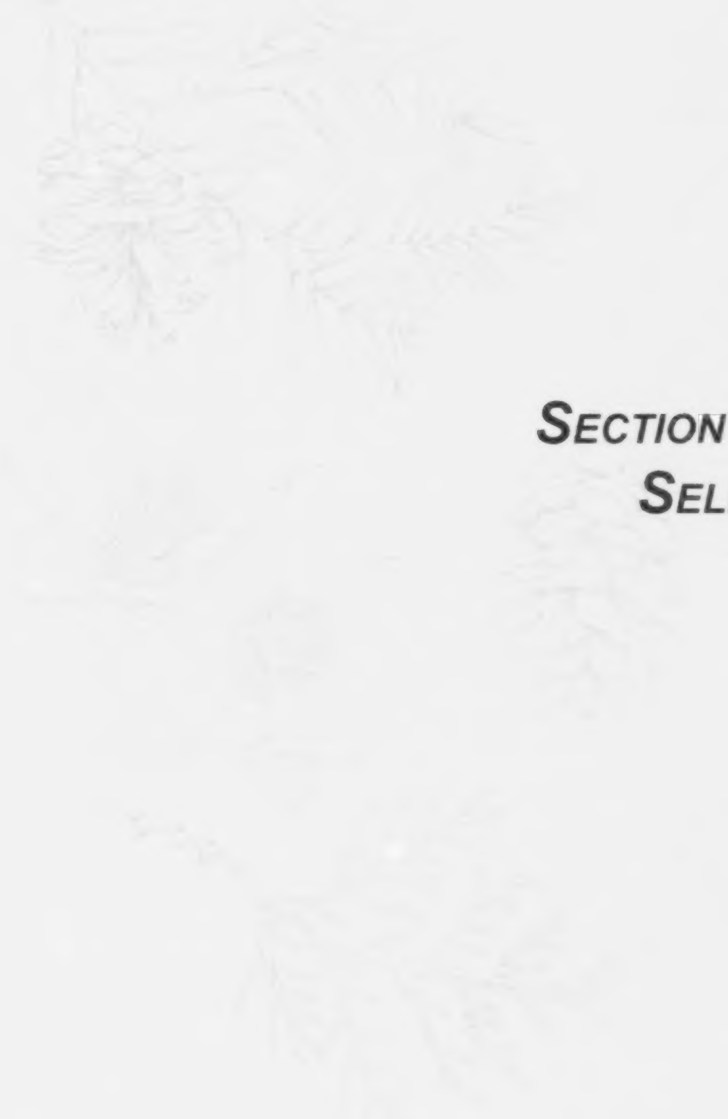

SECTION VII – AUTECOLOGY OF SELECTED FOREST PLANTS

The response of different species to disturbance is not a single ecological characteristic, but the collective strategies of a plant species to evade, escape, or resist disturbance. This includes all the adaptive mechanisms plants have evolved (i.e. life history characteristics, regeneration strategies, and physiological traits) to respond to various kinds of natural disturbances such as fire, browsing, insects, and disease. Plants use these same mechanisms to respond to silvicultural disturbances (e.g. overstorey removal, mechanical site preparation, prescribed burning, cutting, and herbicides). With the focus on integrated forest management and the development of vegetation management techniques to promote sustainable forestry, it has become critical for forest managers to use information on plant autecology to predict how crop and non-crop species will respond to natural and silvicultural disturbances.

Autecology is the branch of ecology dealing with the study of the responses and adaptations of individual species or populations to their environment (Barbour *et al.* 1987). The work of Haeussler and Coates (1986) in British Columbia was the first comprehensive literature review of the autecological characteristics of forest plant species. Their work has inspired five similar literature reviews (Sims *et al.* 1990, Bell 1991, Louter *et al.* 1993, Bentley and Pinto 1994, Bell and Kershaw, in prep.) and two autecology guides of Ontario's forest plants (Buse and Bell 1992, Arnup *et al.* 1994). These publications include information on eight conifer, 85 deciduous tree and shrub, 27 herb, 17 graminoid, three fern, three lichen, three moss, and seven *Sphagnum* species found in Ontario.

The species presented in this section are trees, shrubs, and herbs found in boreal mixedwoods of Ontario. Common and scientific names are consistent with current names used in Ontario (Newmaster *et al.* 1998). In each table, species are grouped by life form and listed alphabetically by scientific name. Their nomenclature, growth habit, reproductive characteristics, phenology, ecophysiology, and response to disturbance have been summarized in ten tables. Although not provided in this guide, taxonomic descriptions of stems, leaves, flowers, and fruits accompanied by an illustration of each species are available in Chambers *et al.* (1996) and Baldwin and Sims (1997).

Methods to control or promote the growth of a species should be based on growth habit, reproductive characteristics, environmental requirements, and competitive status.

Growth habit determines relative competitiveness in a forest community, and includes:

- life cycle
- longevity
- growth pattern

Plants have one of three life cycles: annuals, biennials, or perennials and complete their life cycles within one, two, and more than two growing seasons, respectively. Annuals and biennials rarely constitute a serious obstacle to conifer regeneration because of their short lifespans. They may temporarily reduce height growth or smother small conifer seedlings through snow load or leaf litter.

The longevity of perennial plant species (e.g. trees, shrubs, and most persistent herbs) can contribute to their competitive status. Long-lived species generally outcompete short-lived species unless the short-lived species are more successful competitors. Perennials also often create greater competition because of their rapid regrowth following a disturbance. All species presented in Table 1 are perennials.

Growth patterns (e.g. stem height, clone size, rooting zone, and root grafting) also contribute to a plant's competitive status. For example, the maximum height that a species can achieve will determine if it will be a competitor for a few years or for many years. Root grafting permits subordinate plants to obtain nutrients from dominant plants.

The regional FECs provide quantitative information on the relationships between vegetation and site characteristics. This information can be used to help predict the occurrence of various plant species, and identify the most important competitive species on a given ecosite (site type). This information, combined with knowledge of the moisture, nutrients, and light requirements of a plant species, can be used to tailor silvicultural practices to promote or retard the growth of selected species. Information on the frequency of occurrence of selected species is presented for northwestern Ontario FEC V-types (Table 2) and northeastern Ontario ES-types (Table 3).

Table 1. Form, longevity, and growth habit of selected species.

	Common Name	Scientific Name	Longevity (years)	Maximum Stem Height (metres)	Maximum Area of Clone (metres)	Zone of Rooting	Forms Root Graft
Trees	Balsam fir	*Abies balsamea*	150	25	—	org/min	—
	Red maple	*Acer rubrum*	150	30	—	mineral	yes
	Sugar maple	*Acer saccharum* var. *saccharum*	300 – 400	39	—	mineral	yes
	Yellow birch	*Betula alleghaniensis*	300 – 350	30	—	mineral	—
	White birch	*Betula papyrifera*	140	28	1	mineral	—
	Black ash	*Fraxinus nigra*	250 – 300	18 – 21	—	—	—
	Tamarack	*Larix laricina*	150 – 180	30 – 35	—	org/min	—
	White spruce	*Picea glauca*	250 – 300	34	—	mineral	—
	Black spruce	*Picea mariana*	250+	25	—	org/min	yes
	Jack pine	*Pinus banksiana*	200+	30	—	mineral	—
	Red pine	*Pinus resinosa*	200+	34	—	mineral	yes
	Eastern white pine	*Pinus strobus*	300+	38	—	mineral	yes
	Balsam poplar	*Populus balsamifera* ssp. *balsamifera*	200	30	—	mineral	—
	Large tooth aspen	*Populus grandidentata*	80 – 100	18 – 24 (30)	—	mineral	—
	Trembling aspen	*Populus tremuloides*	120	34	965,000	mineral	—
	Mountain ashes	*Sorbus* spp.	—	10	—	min/org	—
	Eastern white cedar	*Thuja occidentalis*	400 – 500	21 – 24	—	org/min	—
	White elm	*Ulmus americana*	300	38	—	mineral	—

Table 1 (cont.).

	Common Name	Scientific Name	Longevity (years)	Maximum Stem Height (metres)	Maximum Area of Clone (metres)	Zone of Rooting	Forms Root Graft
Shrubs	Mountain maple	*Acer spicatum*	—	3	2	organic	no
	Speckled alder	*Alnus incana* ssp. *rugosa*	—	4	—	min/org	—
	Green alder	*Alnus viridis* ssp. *crispa*	—	3	—	mineral	—
	Serviceberries	*Amelanchier* spp.	40	7	—	min/org	—
	Red-osier dogwood	*Cornus stolonifera*	—	2	—	mineral	—
	Beaked hazel	*Corylus cornuta* ssp. *cornuta*	60	3	2	organic	—
	Bush honeysuckle	*Diervilla lonicera*	—	1	—	mineral	—
	Honeysuckles	*Lonicera* spp.	—	3	—	min/org	—
	Mountain fly honeysuckle	*Lonicera villosa*	—	1	—	organic	—
	Pin cherry	*Prunus pensylvanica*	30	5	—	mineral	—
	Choke cherry	*Prunus virginiana* ssp. *virginiana*	—	4	—	mineral	—
	Currants	*Ribes* spp.	—	3	—	mineral	—
	Prickly rose	*Rosa acicularis* ssp. *sayi*	—	1	—	mineral	—
	Wild red raspberry	*Rubus idaeus* ssp. *melanolasius*	—	2	20	mineral	—
	Sparse-flowered thimbleberry	*Rubus parviflorus*	—	0.5 – 2.5	—	mineral	—
	Willows	*Salix* spp.	40+	1 – 6	—	org/min	—
	Red-berried elderberry	*Sambucus racemosa* ssp.*pubens*	—	4	—	min/org	—
	Low sweet blueberry	*Vaccinium angustifolium*	150	0.5	—	org/min	—
	Velvet-leaf blueberry	*Vaccinium myrtilloides*	—	0.5	300+	org/min	—
	Viburnums	*Viburnums* spp.	—	2	—	mineral	—
Other	Large-leaved aster	*Aster macrophyllus*	—	1	—	mineral	—
	Canada blue-joint	*Calamagrostis canadensis*	—	1 – 2	—	min/org	—
	Sedges	*Carex* spp.	—	1	—	min/org	—
	Field bindweed	*Convolvulus arvensis*	—	—	—	mineral	—
	Fireweed	*Epilobium angustifolium*	20+	2	—	mineral	—
	Eastern bracken fern	*Pteridium aquilinum* var. *latiusculum*	100	1 – 2	—	org/min	no

Table 2. Frequency of occurence of selected plant species for boreal mixedwood Northwest Region V-types (Buse and Bell 1992).

	Common Name	V-Types																
		Mainly Hardwoods									Conifer Mixedwoods					Conifer		
		1	2	4	5	6	7	8	9	10	14	15	16	19	20	24	25	31
Trees	Balsam fir	■	■	■	▓	■	■	■	■	■	■	■	■	■	▒	■	■	■
	White birch	▒	▒	▓	▓	▒	▒	▒	▒	▒	▒	▒	▓	▒	▓	▒	▒	▒
	White spruce	▒	▓	▒		▒	▒	▓	■	▒	▒	■	■			■	■	▒
	Black spruce	▒		▓	▒		▒	▓	▒	■	▒	▒	▓	■	■	▒	▓	■
	Jack pine			▒				▒	▒	▓			▒	▒	▓		▒	■
	Red pine																	
	White pine																	
	Balsam poplar	▓																
	Trembling aspen	▒			▓	■	▓	▓	▓	▓	▓	▒	▒	▓		▒		▒
Shrubs	Mountain maple	▓	■	▓	▓	■	▓	■	▓		■	▓	▓	▒		▓	▒	
	Speckled alder	▓	▓				▒		▒					▒		▒		
	Green alder			▒	▒				▒	▓				▒	▒			▒
	Serviceberries	▓	▒	▓	▓	▒	▒	▓	▓	▓	▒	▓	▒	▓		■	▓	▒
	Red-osier dogwood	▓	▓		▒		▒				▒	▒				▒		
	Beaked hazel	▒	▒	▒	■	▓	▓	■	■	▒	▓	▓	▒			▓	▒	▒
	Pin cherry																	
	Choke cherry	▒	▓		▒		▒		▒									
	Currants	■	■	▒	▒	▒	▓	▒	▒	▒	▒	▓	▒	▒		▓		
	Prickly rose	■			▓	▒	▓	▓	▓	▒	▒	▓	▒	▓		▓	▓	▓
	Wild red raspberry	▓	▒		▒				▒			▒				▒		
	Willows																	
	Low sweet blueberry			▓	▒			▒	▒	▓	▒	▒	▒	▓	▓		▒	▓
	Velvet-leaf blueberry			▓	▒		▒	▒	▒	▓	▒		▓	▓	▓	▒	▒	■
Other	Large-leaved aster	▓	▒		▒	▒	▓		▒	▒	▒	▒	▒	▒		▓	▒	
	Canada blue-joint	▒	▒		▒				▒	▒		▒		▒			▒	
	Sedges	▓	■	▒	▒	▒	▒	▒			▓	▒		▒		▓	▒	
	Fireweed	▒			▒				▒	▓				▒				
	Eastern bracken fern				▒				▒									

Absent ░ 1 - 25% ▒ 26 - 50% ▓ 51 - 75% ■ 76 - 100%

Table 3. Percentage cover for selected plant species by Northeast Region boreal mixedwood ecosites (Taylor *et al.* 2000).

ES	3	5f	5m	6f	6m	6c	7f	7m	7c	9r	10
Trees											
Abies balsamea				(4)	(5)	(3)	(4)	(4)	(4)	(3)	
Acer rubrum											
Acer saccharum ssp. *saccharum*											
Betula alleghaniensis											
Betula papyrifera	4						(3)	(3)	(3)	(4)	
Larix laricina											
Picea glauca	(4)					(4)	(4)	(4)	(4)	5	
Picea mariana	(4)	5	5	4	(4)	(4)					(4)
Pinus banksiana	(4)		(4)			(4)					
Pinus resinosa											
Pinus strobus											
Populus balsamifera ssp. *balsamifera*											(5)
Populus tremuloides	4			(5)	5	5	5	5	5		5
Thuja occidentalis											
Shrubs											
Abies balsamea	4	3	4	3	3	3	3	3	4	3	3
Acer rubrum											
Acer saccharum ssp. *saccharum*											
Betula alleghaniensis											
Betula papyrifera	2		(1)	(2)		(2)	(2)	(2)	(2)	(2)	
Larix laricina											
Picea glauca	(2)					(2)	(2)	(2)	(2)		(2)
Picea mariana	3	3	3	2	(3)	(3)				(2)	(3)
Pinus banksiana											
Pinus resinosa											
Pinus strobus											
Populus tremuloides	(2)			(2)	(2)	(2)	(2)	(2)	(2)		(2)
Thuja occidentalis										(4)	

Cover values are given for species occuring on more than two-thirds of sample plots in an ecosite.
Species in brackets are those occurring on more than one-third but less than two-thirds of plots.
Codes: 1 = 1%, 2 = 2 to 5%, 3 = 6 to 10%, 4 = 11 to 20%, 5 = 21 to 40%, 6 > 40%.

Table 3 (cont.).

ES	3	5f	5m	6f	6m	6c	7f	7m	7c	9r	10
Shrubs											
Acer spicatum	(3)						5	5	5		(4)
Alnus incana ssp. *rugosa*		(2)		(3)	4					4	(4)
Alnus viridis ssp. *crispa*											
Amelanchier spp.	(2)		(1)	(1)	2	2	(2)	(2)		(2)	(1)
Cornus stolonifera					(2)					(2)	(2)
Corylus cornuta ssp. *cornuta*	(3)				(2)	(2)	3	3	4		(3)
Diervilla lonicera	2		(2)	(3)	3	3	(3)	3	3		
Lonicera canadensis				(1)	(2)		2	(2)	(2)	(2)	(2)
Lonicera villosa											
Prunus virginiana ssp. *virginiana*											
Ribes lacustre				(2)			(2)			(2)	(2)
Ribes triste				(1)			(2)			(1)	(2)
Rosa acicularis spp. *sayi*		(2)		2	2	(2)	(2)			(1)	(2)
Rubus idaeus ssp. melanolasius				(2)	(2)					(3)	(2)
Salix spp.											
Sorbus decora	(2)		(2)	(1)	(2)	(1)	(2)	(2)	(2)	2	(2)
Vaccinium angustifolium	2	(2)	(2)	(2)	(1)	2					(2)
Vaccinium myrtilloides	2	2	2	(2)	(2)	2					(2)
Viburnums edule				(2)	(1)		(2)				(2)
Herbs											
Aster macrophyllus	(2)		(2)	4	3	3	4	4	3	(3)	(3)
Graminoids and Ferns											
Calamagrostis canadensis					(2)	(1)					(2)
Carex spp.		(1)		(2)	(2)		(2)	(2)	(2)	2	(2)
Pteridium aquilinum var. *latiusculum*	(3)							(4)	(2)		

Cover values are given for species occuring on more than two-thirds of sample plots in an ecosite.
Species in brackets are those occurring on more than one-third but less than two-thirds of plots.
Codes: 1 = 1%, 2 = 2 to 5%, 3 = 6 to 10%, 4 = 11 to 20%, 5 = 21 to 40%, 6 > 40%.

Tables 2 and 3 should only be considered as guides. The natural variability that characterizes forests throughout northern Ontario accounts for species that are not listed for specific V- or ES-types but still may occur. In addition, since data collection was directed at mature forest ecosystems, the tables do not necessarily indicate species distributions in non-forested or disturbed habitats.

Plant species with high reproductive capabilities are more difficult to control and easier to promote than species with limited reproductive capabilities. Almost all plants reproduce both vegetatively (asexually) and sexually (Tables 4 and 5).

Vegetative (asexual) reproduction (Table 4) can occur through root suckers, rhizomes, root collar and stem sprouts, and layering. Vegetative reproduction is generally more important than sexual reproduction in the rapid recovery of plant cover immediately following a disturbance. For example, sprouting from suckers connected to parent plants with established food reserves and water supply (Zasada 1971) facilitates regrowth of site-adapted individuals without depending on seed supply, dispersal, and viability or seedbed conditions.

Sexual reproduction can be divided into three categories: reproductive characteristics, seed dispersal characteristics, and seed germination requirements. Reproductive characteristics include: reproduction class (monoecious, dioecious, or perfect), propagule fruit type, minimum seed bearing age, periodicity of large seed crops, and seedling regeneration strategy (Table 5). Potential seed production for each species ranges from hundreds to millions of seeds per plant per year. Those species that reach sexual maturity and produce large amounts of seed early in their life cycle have a competitive advantage over species that first produce seeds at older ages (Zasada 1988). Although annual reproductive potential is rarely realized for any given species, total failures seldom occur (Zasada 1988). Plant species, which are seemingly rare or absent in mature forest stands, may become established from buried seeds and quickly dominate the pioneer vegetation community following harvest, fire, or other major disturbances. Seed bank species composition and seed densities may vary greatly from site to site (Kramer and Johnson 1987). While it is possible to eradicate species with short-lived seeds using control strategies that eliminate seed production, this is not a feasible strategy with species that have long-lived seeds. Knowledge of seed longevity in the soil helps to predict weed population dynamics (Conn and Farris 1987) and develop integrated vegetation management plans. For a comprehensive review of the sexual reproductive characteristics of plant species, refer to Schopmeyer (1974) and Young and Young (1992).

Factors affecting seed dispersal include seed type and size, time of seed ripening (phenology) and distance and mode of dispersal (Table 6). Seed type and size directly affect seed dispersion. For example, small winged seeds are capable of travelling several kilometres. Successful regeneration is often dependent upon seed arrival coinciding with a disturbance (i.e. suitable seedbed and microclimatic conditions) as many wind-borne seeds have a limited period of viability and new seedlings cannot compete with extensive competition from established plants (Marks 1974). Seeds are dispersed by wind, water, gravity, mammals, and birds, each influencing the distance travelled from the parent plant.

Regeneration from seed requires the dispersal of abundant viable seed to microsites, or seedbeds, that provide the environmental conditions and resources needed to support germination and establishment (Farmer 1996) (Table 7). The seed of most forest tree species has physiological or physical dormancy at the time of dispersal that must be overcome before germination can occur. Following exposure to the appropriate conditioning environment (e.g. chilling requirement) dormancy is broken and seed germination is dependent on moisture, temperature, and aeration. Within a species, the degree of dormancy and temperature regime for optimal germination varies with provenance. Seed viability also varies among individuals, within individuals from year to year, and is typically higher during years with heavy seed crops.

Following establishment, the microsite must provide young seedlings with sufficient water, nutrients, and light to support a competitive growth rate. The microsite must also be relatively free of competition, pathogens, and insects, etc. Failure to obtain adequate resources can reduce growth and survival.

Table 4. Vegetative (asexual) reproduction methods of selected species.

		Root Origin		Shoot Origin		
	Common Name	**Root Suckers**	**Rhizomes**	**Root Collar Sprouts**	**Lower Stem Sprouts**	**Layering (stolons)**
Trees	Balsam fir	nil	nil	nil	nil	secondary
	Red maple	nil	nil	primary	secondary	secondary
	Sugar maple	secondary	nil	primary	secondary	nil
	Yellow birch	nil	nil	primary	secondary	nil
	White birch	nil	nil	primary	secondary	nil
	Black ash	secondary	—	primary	—	—
	Tamarack	nil	nil	—	—	primary (north)
	White spruce	nil	nil	nil	nil	nil
	Black spruce	nil	nil	nil	nil	primary
	Jack pine	nil	nil	nil	nil	nil
	Red pine	nil	nil	nil	nil	nil
	Eastern white pine	nil	nil	nil	nil	nil
	Balsam poplar	primary	nil	secondary	secondary	nil
	Large tooth aspen	primary	—	secondary	secondary	—
	Trembling aspen	primary	nil	secondary	secondary	nil
	Mountain ashes	nil	nil	secondary	unknown	nil
	Eastern white cedar	nil	nil	nil	nil	primary (swamps)
	White elm	nil	nil	primary	—	nil

Table 4 (cont.).

		Root Origin		Shoot Origin		
	Common Name	**Root Suckers**	**Rhizomes**	**Root Collar Sprouts**	**Lower Stem Sprouts**	**Layering (stolons)**
Shrubs	Mountain maple	nil	nil	primary	secondary	secondary
	Speckled alder	secondary	nil	primary	secondary	secondary
	Green alder	unknown	nil	primary	secondary	nil
	Serviceberries	secondary	nil	primary	secondary	secondary
	Red-osier dogwood	secondary	nil	secondary	secondary	primary
	Beaked hazel	primary	nil	secondary	secondary	secondary
	Bush honeysuckle	nil	primary	unknown	secondary	nil
	Honeysuckles	nil	secondary	secondary	primary	nil
	Fly honeysuckle	nil	secondary	unknown	primary	unknown
	Pin cherry	primary	nil	secondary	secondary	nil
	Choke cherry	primary	nil	secondary	secondary	nil
	Currants	nil	secondary	nil	secondary	primary
	Prickly rose	nil	primary	secondary	secondary	secondary
	Wild red raspberry	nil	primary	primary	primary	unknown
	Sparse-flowered thimbleberry	nil	primary	primary	nil	unknown
	Willows	secondary	nil	primary	secondary	secondary
	Red-berried elderberry	secondary	nil	secondary	primary	secondary
	Low sweet blueberry	nil	primary	secondary	secondary	nil
	Velvet-leaf blueberry	nil	primary	secondary	secondary	nil
	Viburnums	nil	secondary	primary	unknown	secondary
Other	Large-leaved aster	nil	primary	nil	nil	nil
	Canada blue-joint	nil	primary	nil	nil	nil
	Sedges	nil	primary	nil	nil	nil
	Field bindweed	nil	primary	nil	nil	nil
	Fireweed	nil	secondary	nil	nil	nil
	Eastern bracken fern	nil	primary	nil	yes	nil

Table 5. Sexual reproduction methods of selected species.

	Common Name	Reproduction Class	Propagule Type	Minimum Seed Bearing Age (year)	Periodicity of Large Seed Crops (year)	Seedling Regeneration Strategy[1]
Trees	Balsam fir	monoecious	cone	10 – 15	2 – 4	SB
	Red maple	monoecious	samara	4	annually	SB
	Sugar maple	monoecious	samara	40 – 60	annually	SB
	Yellow birch	monoecious	catkin	40	annually	SSB
	White birch	monoecious	catkin	15	2	CSC
	Black ash	dioecious	samara	—	3 – 4	SSB
	Tamarack	monoecious	cone	4 – 15	3 – 6	CSC
	White spruce	monoecious	cone	10	2 – 6	SC
	Black spruce	monoecious	cone	10 – 15	1 – 4	SC
	Jack pine	monoecious	cone	3 – 15	3 – 4	SC
	Red pine	monoecious	cone	2 – 25	3 – 7	CSC
	Eastern white pine	monoecious	cone	2 – 25	3 – 5	CSC
	Balsam poplar	dioecious	catkin	8 – 10	annually	CSC
	Large tooth aspen	dioecious	catkin	10	2 – 3	CSC
	Trembling aspen	dioecious	catkin	10 – 20	4 – 5	CSC
	Mountain ashes	perfect	pome	15	annually	CSC
	Eastern white cedar	monoecious	cone	6	2 – 5	CSC
	White elm	perfect	samara	15	annually	CSC

[1] SB = seedling bank / SSB = soil seed bank / CSC = current seed crop / SC = serotinous cones

Table 5 (cont.).

	Common Name	Reproduction Class	Propagule Type	Minimum Seed Bearing Age (year)	Periodicity of Large Seed Crops (year)	Seedling Regeneration Strategy[1]
Shrubs	Mountain maple	monoecious	samara	—	—	CSC
	Speckled alder	monoecious	catkin	7	annually	CSC
	Green alder	monoecious	catkin	5	annually	CSC
	Serviceberries	perfect	pome	—	annually	SSB
	Red-osier dogwood	monoecious	drupe	4	1 – 2	SSB
	Beaked hazel	monoecious	nut	2	5	CSC
	Bush honeysuckle	perfect	capsule	—	—	—
	Honeysuckles	perfect	berry	3	—	—
	Mountain fly honeysuckle	perfect	berry	—	—	—
	Pin cherry	perfect	drupe	4	2 – 3	SSB
	Choke cherry	perfect	drupe	2	1 – 2	CSC
	Currants	perfect	berry	3 – 5	2 – 3	SSB
	Prickly ros[illegible]	perfect	hip	2	1 – 2	SSB
	Wild red raspberry	perfect	drupe	2	annually	SSB
	Sparse-flowered thimbleberry	perfect	drupelets	2	annually	SSB
	Willow	dioecious	catkin	2 – 4	—	CSC
	Red-berried elderberry	perfect	drupe	—	annually	SSB
	Low sweet blueberry	perfect	berry	4	—	—
	Velvet-leaf blueberry	perfect	berry	—	—	—
	Viburnums	perfect	drupe	3 – 5	annually	SSB
Other	large-leaved aster	Perfect	berry	—	annually	CSC
	Canada blue-joint	Perfect	caryopsis	—	annually	CSC
	sedges	Perfect/Imperfect	achene	1	—	SSB
	field bindweed	Perfect	capsule	—	annually	SSB
	fireweed	Perfect	capsule	1	annually	CSC
	eastern bracken fern	—	sporangium	2	—	—

[1] SB = seedling bank / SSB = soil seed bank / CSC = current seed crop / SC = serotinous cones

Table 6. Seed dispersal characteristics of selected species.

	Common Name	Seed Type	Averaged Cleaned Seeds/kg	Time of Seed Ripening	Dispersed Distance (maximum)	Primary Mode of Dispersal	Time of Seed Dispersal
Trees	Balsam fir	winged seed	131,120	Aug. – Sept.	160 m	wind, mammals	September
	Red maple	samara	50,352	June – July	660 m	wind	June – July
	Sugar maple	samara	13,420	June – Sept.	100 m	wind	June – Sept.
	Yellow birch	samara	983,000	Aug. – Oct.	100 – 200 m	wind	Aug. – Oct.
	White birch	samara	3,036,000	July – Sept.	100 – 200+ m	wind	Sept. – Apr.
	Black ash	samara	13,500 – 20,900	June – Sept.	—	wind	July – Oct.
	Tamarack	winged seed	550,000 – 710,000	Aug. – Sept.	60 – 70 m	wind	Sept. – Oct.
	White spruce	winged seed	497,200	Aug. – Sept.	40 – 60 m	wind, mammals	Aug. – Jan.
	Black spruce	winged seed	1,258,400	Aug. – Sept.	200 m	wind, mammals	Sept. – Apr.
	Jack pine	winged seed	288,200	September	40 – 60 m	wind, mammals	all year
	Red pine	winged seed	114,400	Aug. – Oct.	20 – 40 m	wind	Oct. – Nov.
	Eastern white pine	winged seed	56,320	Aug. – Sept.	100 – 300 m	wind, mammals	September
	Balsam poplar	seed	—	June – July	several km	wind, water	late June – July
	Large tooth aspen	seed	5,600,000	June	several km	wind	June
	Trembling aspen	seed	5,600,000	June	several km	wind	June
	Mountain ashes	seed	352,423	Aug. – Sept.	—	birds, mammals	Aug. – Mar.
	Eastern white cedar	winged seed	763,000	August	45 – 60 m	wind, mammals	September
	White elm	samara	156,000	May	90 – 400 m	wind, water	June
Shrubs	Mountain maple	samara	50,866	Sept. – Oct.	—	wind, water	Oct. – Dec.
	Speckled alder	nut	660,000	August	30 m	wind, water	October
	Green alder	nut	2,816,000	Aug. – Oct.	—	wind	Aug. – Oct.
	Serviceberries	seed	180,800	late June – Aug.	—	birds, mammals	August

Table 6 (cont.).

	Common Name	Seed Type	Averaged Cleaned Seeds/kg	Time of Seed Ripening	Dispersed Distance (maximum)	Primary Mode of Dispersal	Time of Seed Dispersal
Shrubs (cont.)	Red-osier dogwood	stone	40,700	July – Oct.	—	birds, mammals	Oct. – winter
	Beaked hazel	nut	1,208	Aug. – Sept.	—	birds, mammals	—
	Bush honeysuckle	seed	—	July – Sept.	—	birds, mammals	—
	Honeysuckles	seed	312,775 – 719,163	late June – Oct.	—	birds, mammals	—
	Mountain fly honeysuckle	seed	—	June – Sept.	—	birds, mammals	June – Sept.
	Pin cherry	stone	31,240	late July - Aug.		mammals	—
	Choke cherry	stone	10,538	Aug. – Sept.	—	birds, mammals	Aug. – Sept.
	Currants	seed	—	August	—	birds, mammals	Aug. – Oct.
	Prickly rose	achene	—	late summer – early fall	—	birds, mammals	late spring
	Wild red raspberry	seed	721,600	July – Oct.	—	birds, mammals	July – Oct.
	Sparse-flowered thimbleberry	seed	—	Aug. – Sept.	—	birds, mammals	Aug. – Sept.
	Willows	seed	4,989,600	June – July	several km	wind, water	June – July
	Red-berried elderberry	stone	629,956	July – Aug.	—	birds, mammals	June – Nov.
	Low sweet blueberry	seed	4,338,783	July – Aug.	—	birds, mammals	August
	Velvet-leaf blueberry	seed	—	July – Aug.	—	birds, mammals	August
	Viburnums	stone	30,464	July – Sept.	—	birds, mammals	Spring
Other	Large-leaved aster	seed	—	September	—	wind	—
	Canada blue-joint	grain	7,346,687	Aug.	—	wind	Aug. – Sept.
	Sedges	achene	—	July – Sept.	—	wind	Aug. – Sept.
	Field bindweed	achene	—		—	wind	—
	Fireweed	plumed seed	—	Aug. – Sept.	10 - 300 km	wind	Aug. – Sept.
	Eastern bracken fern	spore	—	—	—	wind, water	—

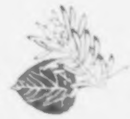

Table 7. Seed germination characteristics of selected tree species.

Species	Viable Seeds per kg	Dormancy[1]	Cold Stratification Period[2] (days)	Percent Germination[3]	Germination Temperature (°C)[4]			Preferred Seedbed[5]
					Low	Optimal	High	
Balsam fir	32,800	C	21 – 90	25	7 – 12	15 – 27	30	MS, DW, BD, PM
Red maple	30,000	None, C	30 – 90	50 – 85	—	1 – 10	—	MS, BD
Sugar maple	8,500	C	35 – 90	50 – 60	—	1 – 5	7	MS
Yellow birch	467,000	C	21 – 30	20 – 40	7 – 12	18 – 29	—	MS, BD, HM, DW
White birch	1,057,000	None, C	60	15 – 60	3	18 – 30	—	MS, HM, DW
Black ash[6]	3,500	C, P, IE	90	20 – 75	—	—	—	MS
Tamarack	351,000	None, C	21 – 60	40 – 50	12	18 – 21	24	MS, O, SM, BO
White spruce	391,000	C	21 – 30	55 – 70	5	14 – 24	35	MS, HM, DW, BD, PM
Black spruce	888,000	None, C	14 – 21	60 – 90	7	12 – 28	34	MS, SM, PM, BO, BD
Jack pine	273,000	None, C	14	70 – 85	—	16 – 27	—	MS, BD
Red pine	102,000	None, C	14 – 21	75 – 85	7	15 – 34	—	MS, BD, PM
Eastern white pine	46,000	C	30 – 60	60 – 90	12	18 – 24	30	MS, PM, BD
Balsam poplar[7]	—	None	0	> 90	5	10 – 40	45	MS
Large tooth aspen[7]	4,200,000	None	0	> 80	5	10 – 29	35	MS
Trembling aspen[7]	4,200,000	None	0	> 75	—	2 – 30	35	MS, H
Mountain ashes[8]	65,000	C	90 – 120	15 – 20	—	20 – 30	—	—
Eastern white cedar	520,000	None, C	21 – 30	35 – 60	14 – 18	24 – 28	34	DW, MS, H, SM, BO
White elm	47,000	None	none	10 – 60	—	10 – 30	—	MS, DW, H

Notes for Table 7:

1. Dormancy refers to a state that prevents germination under environmental conditions unfavourable for growth. Dormancy may be due to the presence of biochemical inhibition (C), physical properties of the seedcoat (P), or an immature embryo (IE). Only more northern provenances of some species may possess dormancy (e.g. red maple).
2. Seedlots within a species may vary in degree of biochemical dormancy such that stratification may not be necessary for high percent germination. For those species sometimes lacking dormancy, a stratification period is identified, which may be higher during years of heavy seed crops.
3. This column shows the percent germination expected from natural seedfall (filled and unfilled seed) that has been stratified (where necessary) and exposed to optimal temperatures for germination.
4. This column shows the temperatures below which percent germination of non-dormant, fully imbibed seed is markedly reduced (low), optimal for germination, or above which percent germination is significantly reduced (high).
5. Seedbed preferences are shown in approximate order of decreasing receptivity. Seedbeds include mineral soil (MS), humus (H), humus/soil mixture (HM), pioneer mosses (PM), *Sphagnum* mosses (SM), decaying wood (DW), burned duff (BD), burned organic soils (BO) and organic (O). Litter or forest duff are generally poor seedbeds and are not listed. Receptivity of all seedbeds increases when precipitation and humidity are high enough to maintain seedbed moisture conditions adequate to support germination and establishment. Therefore, thin, moist litter layers may be receptive. Decayed wood may only be receptive when occurring in the shelter of uncut stands where moisture content remains high. Certain seedbeds occur only on specific ecosites (e.g. *Sphagnum* moss) and consideration of the ranking of those seedbeds should be restricted to these ecosites.
6. Black ash requires a 60 day, warm incubation period (20 to 25° C) to allow the embryo to mature prior to stratification.
7. Seed viability (i.e. percent germination) of *Populus* spp. declines rapidly within a few weeks of dispersal.
8. Information supplied refers to *Sorbus americana*.

Note: Germination of dormant seeds may be improved in the presence of light. It is not an absolute prerequisite for germination of non-dormant seed of any of the species listed. Seed moisture contents of 35 to 45 percent of oven dry weight are optimal for the germination of the species listed. This target moisture content can be achieved by soaking seeds in aerated water for 24 to 48 hours.

Resource limitations may result from weather events, (e.g. drought, flooding) site limitations (e.g. soil infertility), and competition with neighbouring vegetation (e.g. shading). Tree species vary widely in their capacity to tolerate and adapt to environmental stresses and resource limitations. Knowledge of species resource requirements and their tolerance to environmental stress is useful in planning forest management activities to favour the growth of crop species (Table 8).

Response to Disturbance

The response of plant species to disturbance is dependent upon their life history characteristics, regeneration strategy, and physiological traits (Grime 1977). Plant species have adapted (i.e. evolved through natural selection) to specific combinations of habitat disturbances and resource availability. It is through these adaptations that plants respond to silvicultural disturbances.

Disturbance refers to events at various spatial scales that limit plant biomass accumulation through its partial or total destruction (Grime 1977). Disturbances may be natural (e.g. wildfire, flood, wind) or of human origin (e.g. logging, prescribed burning). Vegetation response to disturbances also depends on the severity of the disturbance, and conditions created by the disturbance. The impact of forest management activities on vegetation response is discussed below.

Overstorey Removal

Species composition of post-logging vegetation is dependent upon the amount of overstorey removed and the harvesting method used. The presence of a residual canopy provides a seed source for natural regeneration and moderates seedbed microclimate, promoting germination (Tables 6 and 7). A reduction in canopy density increases the solar radiation received by a site and alters energy exchange between the atmosphere and the ground. The resultant increases in light availability, diurnal range of air and soil temperatures, and reduction in humidity are greater the larger the reduction in the overstorey. The physiological response of species to changes in microclimate, the resources available, and the environmental stress of the site determine the composition and growth of post-logging vegetation (Table 8). Canopy manipulation to create favourable understorey conditions for target crop species and/or to inhibit non-crop species is fundamental to the success of partial canopy removal methods used to manage mid-tolerant and tolerant species.

Harvest method influences post-logging vegetation through an interaction between the degree of disturbance to the forest floor and the regeneration strategy (Table 9). Disturbance of soil organic layers can stimulate site colonization by seed-banking species. Removal of the organic layer and exposure of mineral soil provides sites for invasion by wind-borne seed. Vegetative reproduction through sprouting or root suckering may also be stimulated or inhibited, depending on the degree of disturbance to stems, roots, and rhizomes. Careful logging techniques can be used to conserve advance reproduction when these plants are to be used as a source of natural regeneration.

Generally, sites where the forest floor remains virtually undisturbed following logging support vegetation that closely resembles the understorey species composition that existed before logging (Dyrness 1973) (Table 9). On these sites, residual species often expand via the sprouting of basal buds, rhizomes, and root suckers following overstorey removal, virtually excluding invading species (Yang and Fry 1981). Typically, winter harvesting disturbs the ground surface less than summer harvesting (Campbell 1981). This may result in less germination of seed from species such as pin cherry, raspberry, or Canada blue-joint.

Prescribed Burning

The response of a plant to fire depends on several factors including fire severity (Table 9), phenology (McLean 1969, Noste *et al.* 1987, Haeussler 1991), and post-fire microsite conditions. Fires can be categorized as light, moderate, or severe (Haeussler 1991). The species composition re-established after light surface fires will closely resemble that of the pre-burn condition, especially where the majority of species regenerate from underground plant parts (Smith and Sparling 1966, Smith and James 1978).

Table 8. Environmental requirements and tolerences to environmental stress.

	Environmental Requirements			Tolerance or Adaption to Environmental Stress[2]					
Species	**Water**	**Nutrients**	**Shade**	**Soil pH[1]**	**Drought**	**Water-logging[3]**	**Frost[4]**	**High Temp**	**Wind[5]**
Balsam fir	M	M	very tolerant	5.0 – 7.0	L	M	L – M	—	L
Red maple	L – M	L – M	tolerant	—	M	M – H	L	—	M
Sugar maple	M	M	very tolerant	5.5 – 7.3	L	L	L – M	—	M
Yellow birch	M	M – H	intermediate	acid intolerant	L	L	L – M	—	M
White birch	M	M	very intolerant*	5.0 – 7.0	M	L	L	L	M
Black ash	—	M	intolerant	4.4 – 8.2	—	M – H	M – H	—	L
Tamarack	L – M	L – M	very intolerant	5.5 – 7.6	L – M	M	M	—	L – M
White spruce	M	M	intermediate to tolerant	4.7– 6.5	L – M	L – M	L – M	—	L – M
Black spruce	L – M	L	intermediate to tolerant	5.0 – 7.0	L – M	M	M	—	L – M
Jack pine	L	L	very intolerant	4.5 – 7.0	H	L	M	—	M – H
Red pine	L	L – M	intolerant	5.2 – 6.5	M – H	L	M	—	H
Eastern white pine	M	M	intermediate	4.7 – 7.3	M	L – M	M – H	—	M – H
Balsam poplar	M – H	M – H	very intolerant	acid intolerant	L	M	L	—	—
Large tooth aspen	M – H	M – H	very intolerant	4.8 – 6.5	M	L – M	M	—	M – H
Trembling aspen	M – H	M – H	very intolerant	5.3 – 6.5	L – M	L – M	L	L	M
Mountain ashes	L – M	M	intolerant	4.5 – 5.5	M	L	L	—	—
Eastern white cedar	M	L – M	tolerant	5.5 – 7.2	M	M – H	M – H	—	L – M
White elm	L – M	M	intermediate	5.5 – 8.0	M	M – H	L – M	—	M

* Some recent studies have shown white birch to be more shade tolerant than previously thought.

Notes for Table 8:

1. This column shows the range in soil pH in which optimal growth occurs. Some species occasionally inhabit extremely acid or alkaline soil microsites outside the range given.
2. Tolerance and adaptations are ranked relative to that expected for young seedlings, with the exception of wind, which refers to windfirmness of mature trees.
3. Waterlogging refers to transient increases in the water table or flooding events where soil moisture content increases dramatically and soil aeration is reduced to injurious levels. Species that inhabit wet soils are not necessarily tolerant of waterlogging.
4. Frost tolerance rankings are based on species differences in time of spring shoot flushing and predisposition to damage by a late spring (June) frost.
5. Tolerances of mechanical damage by wind, in this case, refers to the risk of uprooting or windthrow as opposed to stem breakage. The risk of windthrow is largely a function of rooting habit and rooting depth. Rooting depth of all species is affected by soil depth or depth of the water table, with rooting depth decreasing and risk of windthrow increasing with higher water tables. Species were ranked based on their typical rooting patterns exhibited on commonly inhabited ecosites. For species that inhabit both wet and relatively dry sites (e.g. *Thuja occidentalis*), windthrow tolerance is lower on wetter sites.

Note: Environmental requirements or levels of stress tolerance are ranked as low (L), moderate (M), and high (H). Light requirements are expressed in terms of classical shade tolerance assignments.

In contrast, severe fires consume the litter (LFH) layers and increase mineral soil surface temperatures to lethal levels that can reduce, and in some cases eliminate, the ability of plants to reproduce vegetatively. In these instances, regeneration must be from seed on the site or from adjacent unburned stands. Plant species can be ranked according to relative fire resistance of their root system. "Susceptible" species are those having fibrous root systems or producing stolons or rhizomes growing above mineral soil. "Moderately resistant" species usually have fibrous roots with rhizomes growing less than five centimetres below the mineral soil surface. "Resistant" species are those with rhizomes growing between five and 13 centimetres below the mineral surface and species capable of regeneration from adventitious buds on their tap roots (McLean 1969).

Seasonal changes in soil moisture and carbohydrate reserves of underground plant parts affect the quantity and vigour of regrowth (Noste *et al.* 1987). Soil moisture affects the transfer of heat to underground plant parts and therefore damage to root systems and soil seed banks (Noste *et al.* 1987). Temperatures hot enough to destroy roots, rhizomes, or seeds rarely occur more than a few centimetres below the surface of wet duff (Haeussler 1991).

Post-fire increases in soil moisture, soil temperature, light, and the removal of surface litter and senescent plant parts stimulate both vegetative and seedling growth (Smith and James 1978).

Mechanical Site Preparation

The response of plant species to mechanical disturbance depends on the extent and type of disturbance.

Different types of disturbance (Table 9), differentiated by relative treatment effects on organic and mineral soil layers, have been described (Sutherland and Foreman 1995):

- **Overstorey removed, ground undisturbed:** there is little change to the floristic composition, but the total biomass is reduced.
- **LFH displaced and mineral soil depressed, level or raised:** the composition and structure of the vegetation outside the mineral soil patch is unchanged and there will be no vegetation on the mineral soil until plants seed in or sprout up. Vegetation developed on the mineral soil is often of a different composition than vegetation on the undisturbed areas. Areas of mineral soil are soon occupied by pioneer species, usually by seeding-in.
- **LFH inverted with mineral soil cap:** germination of wind-borne seed on mounds or berms may be inhibited owing to lower soil moisture and higher soil surface temperatures. Rhizomes tend to develop along the berms.
- **LFH and mineral soil mixed:** response differs depending upon the depth and intensity of mixing. For example, deep mixing will reduce the germination potential of the soil seed bank and intense mixing will reduce the potential of root suckers.

Cutting

The effectiveness of a cutting operation is dependent upon the species and sites being cut, the seasonal timing of the cut, and the height, angle, and smoothness of the cut. Cutting is most effective when the target species are not overly dense and do not sprout or sucker. As conifers do not sprout they are easily controlled by this method. Many hardwood species sprout vigorously after cutting (Bell 1991). In general, when a single hardwood stem is severed, it will give rise to multiple shoots. If the original brush was dense, growth after cutting may form a very dense canopy at a lower level and be more competitive than the original brush canopy (Campbell 1981). Stems cut during the dormant season sprout more vigorously than those cut during the growing season because of seasonal variation in carbohydrate resources in underground structures. Cutting when carbohydrate reserves are low, typically after leaf-out in early summer, reduces growth of sprouts (Bell 1991). Cut height also affects vegetative growth. Species that exhibit stem or root collar-sprouting (e.g. alder and dogwood) should be cut as low as possible to the ground (Harrington 1984), while root-suckering species (e.g. aspen) should be cut higher (i.e. 50 to 75 centimetres, but below the live crown) to reduce suckering (Stoeckeler 1947,

Table 9. Relative influence of microsite categories on vegetation (adapted from: Sutherland and Foreman 1995).

Microsite description Effect of disturbance on reproduction ↑ = promotes (↑↑ = strongly promotes) 0 = no effect ↓ = discourages (↓↓ = strongly discourages)			**Vegetative (Asexual) Reproduction**			**Sexual Reproduction**	
			Shoot Origin Sprouting	**Root Origin Sprouting**		**Windborne Seeders**	**Seed Bankers**
			e.g. maple, alder, birch, dogwood, hazel, willow	**Roots in Organic Layer**	**Roots in Mineral Soil**	e.g. birch, fireweed, poplar, willow	e.g. dogwood, cherry, rose, raspberry, blueberry
Microsite Categories				e.g. grasses, blueberry	e.g. poplar, rose, raspberry		
	Undisturbed		0	0	0	0	0
Harvest	Overstorey removed, ground undisturbed		↑↑	↑	↑	0 to ↑[1]	↑
Mechanical Site Preparation	LFH displaced and mineral soil either:	depressed	↓↓	↓↓	↓↓ to ↓[2]	↑↑	↓↓
		level	↓↓ to ↓[3]	↓	↑↑	↑↑	↓
		raised	↓↓	↓↓	↓↓ to ↓[4]	↑	↓↓
	LFH inverted with mineral soil cap		↑ to ↑↑	↓ to ↑[4]	↓	↑	↓
	LFH and mineral soil mixed		↑ to ↑	↓ to ↑	↓ to ↑	↑↑	↑↑
Prescribed Burning	Light[5]		↑↑	↑↑	↑↑	↑	↑↑
	Moderate[6]		↓	↑	↑↑	↑↑	↑
	Severe[7]		↓↓	↓↓	↓	↑↑	↓↓
Cutting	Active	< 25 cm	↑	↑	↑	–	–
		> 25 cm	↑	↑	↑	–	–
	Dormant	< 25 cm	↑↑	↑↑	↑↑	–	–
		> 25 cm	↑↑	↑	↑	–	–

Notes for Table 9:

1. Will be promoted if organic layer is shallow and/or moist.
2. Control of sprouting depends on removal of root systems.
3. Control of sprouting is improved for species that tend to root in the organic layer.
4. Control of sprouting increases with increased depth of scalping.
5. Moss/litter layer is singed. More than 60 percent of the shrub canopy has been consumed. Some leaves and small twigs remain on plants and are either unharmed or slightly singed.
6. Most of the moss/litter layer is charred but not ashed; 40 to 80 percent of the shrub canopy has been consumed. Only medium-sized twigs (0.5 to 1.5 centimetre diameter) remain and are charred.
7. Moss/litter and duff layers have been consumed and only ashes remain on the soil surface. More than 95 percent of the shrub canopy has been consumed, with only large stems (more than 1.5 centimetre diameter) or charred remains of the main stems left.

Wagner *et al.* 1995). The angle and aspect of the cut faces of stumps may affect the sprouting of alder (Harrington 1984). Ragged surfaces created by dull cutting tools are thought to decrease the numbers and vigour of sprouts for tall shrubs and trees (Farnden 1992).

Herbicides

The success of herbicide treatments depends on species' susceptibility to herbicides, phenology, and reproductive characteristics. Herbicide susceptibility plays a very important role in the rate of recovery from treatment. Canada blue-joint, for example, is resistant to 2,4-D and can reproduce rapidly through rhizomes after a 2,4-D application. Knowing the relative susceptibility of species to herbicides licensed for vegetation management enables forest managers to select a herbicide that will provide desired results. Species susceptibility tables for 2,4-D, hexazinone, glyphosate , and triclopyr are presented in Table 10.

Herbicide susceptibility of both crop and non-crop species is directly related to phenology. From a review of the optimum timing of herbicide applications (Carruthers and Towill 1988) and autecology summaries (Bell 1991, Haeussler *et al.* 1990), the following broad recommendations can be made:

- growth-promoting herbicides, such as 2,4-D and triclopyr, are most effective in late July to early August, at the end of rapid shoot elongation
- foliar-active, photosynthesis-inhibiting herbicides, such as glyphosate , are most effective in August when carbohydrates are being translocated to the root system
- soil-active, photosynthesis-inhibiting herbicides, such as hexazinone, are most effective in May to June prior to shoot elongation, when roots are actively growing and the ground is neither frozen nor dried out

Wind-borne and buried seed play a very important role in post-herbicide recovery, especially in the case of foliar-active herbicides. These compounds do not possess soil-active properties and, therefore, do not control post-spray germinants. Fireweed, asters, alder, birch, and Canada blue-joint typically invade herbicide-treated areas via wind-borne seed. Buried seeds, dormant in the soil seed bank for many years, germinate in response to environmental changes following herbicide applications. Red raspberry and pin cherry depend primarily on this reproductive strategy. Generally, recruitment from either wind-borne seed or buried seed can best be controlled with soil-active herbicides.

Soil properties influence the movement of soil-active herbicides into the rooting zone. Effectiveness of root uptake is reduced on fine-textured soils (i.e. clay) and on soils with high organic content. Comparatively greater quantities of chemical are required to control vegetation on these soils than on medium-textured soils.

Application of Autecology Tables

Table 11 provides direction on how to apply autecology Tables 1 through 8. Users are required to apply their knowledge of basic ecology to make interpretations of how plant communities will respond to disturbances caused by silvicultural operations. These interpretations will be site specific and dependent on management objectives. Some of the key considerations to be evaluated at each silvicultural treatment stage, cross referenced to the autecology tables, are summarized in Table 11.

Table 10. Susceptibility of selected competitor and crop species to selected herbicides for forestry use in Ontario.

	Species	2,4-D	Hexazinone	Glyphosate	Triclopyr
Trees	Balsam fir	R	R	R	R
	Red maple	I – R	S – I	S	S – I
	Sugar maple	I – R	—	S	—
	Yellow birch	S	—	—	—
	White birch	S	I	S – I	S
	Black ash	—	—	—	—
	Tamarack	—	—	—	—
	White spruce	R	I – R	R	R
	Black spruce	R	I – R	R	R
	Jack pine	R	S	I – R	I – R
	Eastern white pine	R	I	R	R
	Balsam poplar	S – R	S – I	S – I	S
	Large tooth aspen	—	—	—	—
	Trembling aspen	S – I	S – I	S – I	S
	Mountain ashes	—	S	S	—
	Eastern white cedar	—	—	—	—

Legend:		
	VR	Very Resistant
	R	Resistant
	I	Intermediate
	S	Susceptible
	—	No information

Table 10 (cont.).

	Species	2,4-D	Hexazinone	Glyphosate	Triclopyr
Shrubs	Mountain maple	I – R	I	S – I	S
	Speckled alder	S – I	R	S – I	S
	Green alder	S – I	R	S	S
	Serviceberries	S – R	I	S	S
	Red-osier dogwood	S – I	I – R	I – R	S
	Beaked hazel	S	I – R	S – I	S – I
	Bush honeysuckle	—	I	I	—
	Honeysuckles	—	I	S	R
	Mountain fly honeysuckle	—	I	S	R
	Pin cherry	S	I	S	S
	Choke cherry	S – R	I	S	S
	Currants	I	I	I	S
	Prickly rose	R	I	S – I	S
	Wild red raspberry	R	S	I	S
	Sparse-flowered thimbleberry	S	—	S	—
	Willows	S	I	I – R	S
	Red-berried elderberry	I	I	S – I	S
	Low sweet blueberry	S	VR	S – I	S
	Velvet-leaf blueberry	S	VR	S – I	S
	Viburnums	R	I	S	—
Other	Large-leaved aster	—	S	—	—
	Canada blue-joint	R	S	I	R
	Sedges	R	S	S – I	—
	Field bindweed	I	—	S – I	—
	Fireweed	S – I	I – R	I	S
	Eastern bracken fern	R	S – I	S – I	I – R

Legend:

VR	Very Resistant
R	Resistant
I	Intermediate
S	Susceptible
—	No information

Table 11. Application of the autecology tables.

	Table 1 Form, Longevity, and Growth Habit	**Tables 2 & 3** Vegetation and Ecosites	**Table 4** Vegetative (asexual) Reproduction Methods	**Table 5** Sexual Reproduction Methods
Pre-harvest	Maturity of the stand? Biological rotation of the stand?	Occurrence of crop and non-crop species?	Advance regeneration potential? Could careful logging operations be planned?	Periodicity of good seed crops? Natural seedling regeneration strategy?
Silvicultural System/Harvest Method (also see Table 9)	N/A	Species occurrence? Application and timing of treatment?	Protect advance regeneration? Promote/ inhibit suckering?	Natural seed source availability?
Logging Method	N/A	Species occurrence? Application and timing of treatment?	Protect advance regeneration? Careful logging? Abundance and distribution of slash?	Distribution of cone-bearing slash? Impact of logging on the potential for natural seedling regeneration?
Site Preparation (also see Tables 9 and 10)	Potential for root disturbance?	Species occurrence? Application and timing of treatment?	Protect advance regeneration? Root suckering species? Promotion or inhibition of vegetative reproduction?	Affect of site preparation on the soil seed and seedling banks?
Regeneration	Site occupancy through suckering?	Species occurrence? Application and timing of treatment?	Potential for natural regeneration or competition problems?	Natural seed availability?
Tending (also see Tables 9 and 10)	Translocation of chemicals through root grafts? Canopy structure?	Species occurrence? Application and timing of treatment?	Treatments required to control suckering and basal sprouts?	Invasion of vegetation through seedbank and wind-borne seed?

Table 11 (cont.).

	Table 6 Seed Dispersal Characteristics	**Table 7** Seed Germination Characteristics	**Table 8** Environmental Requirements, Adaptations to Stress
Pre-harvest	Time of year for seed collection? Cut layout pattern? Time of harvest?	Quantity of seed needed for artificial regeneration? Appropriate artificial regeneration techniques (e.g. nursery practices)?	Matching species to site? Predicting regeneration success?
Silvicultural System/Harvest Method (also see Table 9)	Choice of silvicultural system (clearcut, shelterwood, or selection)?	N/A	Selection of silvicultural system?
Logging Method	Seed dispersal at time of harvest?	N/A	Use of slash to protect the site from drought or high temperatures?
Site Preparation (also see Tables 9 and 10)	Use of timing of site preparation to promote crop or inhibit competitor regeneration?	Seedbed requirements?	Microsite amelioration?
Regeneration	Amount of seed needed? Dispersal distances? Methods and timing for natural regeneration?	Amount of seed needed?	Microsite selection?
Tending (also see Tables 9 and 10)	Invasion from wind-borne seed?	N/A	Competition for water, light, and nutrients? Nurse crop potential?

SPECIES LIST

Trees

Abies balsamea	Balsam fir
Acer rubrum	Red maple
Acer saccharum ssp. *saccharum*	Sugar maple
Betula alleghaniensis	Yellow birch
Betula papyrifera	White birch
Fraxinus nigra	Black ash
Fraxinus pennsylvanica	Red ash – Green ash*
Larix laricina	Tamarack – Larch*
Picea glauca	White spruce
Picea mariana	Black spruce
Pinus banksiana	Jack pine
Pinus resinosa	Red pine
Pinus strobus	Eastern white pine – White pine*
Populus balsamifera ssp. *balsamifera*	Balsam poplar
Populus grandidentata	Large tooth aspen
Populus tremuloides	Trembling aspen
Quercus macrocarpa	Bur oak
Salix spp.	Willows
Tilia americana	American basswood
Thuja occidentalis	Eastern white cedar – White cedar*
Ulmus americana	White elm

Shrubs

Acer spicatum	Mountain maple
Alnus incana ssp. *rugosa*	Speckled alder
Alnus viridis ssp. *crispa*	Green alder
Amelanchier spp.	Serviceberries
Andromeda polifolia ssp. *glaucophylla*	Bog rosemary
Arctostaphylos uva-ursi	Common bearberry
Betula pumila	Swamp birch – Dwarf birch*
Chamaedaphne calyculata	Leatherleaf
Cornus canadensis	Bunchberry
Cornus stolonifera	Red-osier dogwood
Corylus cornuta ssp. *cornuta*	Beaked hazel
Diervilla lonicera	Bush honeysuckle

Epigaea repens	Trailing arbutus
Gaultheria hispidula	Creeping snowberry
Gaultheria procumbens	Wintergreen
Kalmia angustifolia	Sheep laurel
Kalmia polifolia	Bog laurel – Pale laurel*
Ledum groenlandicum	Labrador-tea
Linnaea borealis ssp. *longiflora*	Twinflower
Lonicera canadensis	American fly honeysuckle – Canada honeysuckle*
Lonicera hirsuta	Hairy honeysuckle
Lonicera involucrata	Involucred fly honeysuckle – Four-lined honeysuckle*
Lonicera villosa	Mountain fly honeysuckle
Lonicera spp.	Honeysuckles
Prunus pensylvanica	Pin cherry
Prunus virginiana ssp. *virginiana*	Choke cherry
Rhamnus alnifolia	Alder-leaved buckthorn
Ribes glandulosum	Skunk currant
Ribes hirtellum	Smooth gooseberry
Ribes lacustre	Swamp black currant – Bristly black currant*
Ribes spp.	Currants and Gooseberries
Ribes triste	Wild red currant – Swamp red currant*
Rosa acicularis ssp. *sayi*	Prickly rose – Bristly wild rose*
Rubus idaeus ssp. *melanolasius*	Wild red raspberry
Rubus parviflorus	Sparse-flowered thimbleberry
Rubus pubescens	Dwarf raspberry
Salix bebbiana	Bebb's willow
Salix spp.	Willows
Sambucus racemosa ssp. *pubens*	Red-berried elderberry
Sorbus americana	American mountain ash
Sorbus decora	Showy mountain ash
Sorbus spp.	Mountain ashes
Taxus canadensis	Ground hemlock
Vaccinium angustifolium	Low sweet blueberry – Early low blueberry*
Vaccinium myrtilloides	Velvet-leaf blueberry
Vaccinium oxycoccos	Small cranberry
Viburnum edule	Squashberry
Viburnum spp.	Viburnums

Herbs

Actaea rubra	Red baneberry
Actaea spp.	Baneberries
Anemone quinquefolia var. *quinquefolia*	Wood anemone
Aralia nudicaulis	Wild Sarsaparilla – Sarsaparilla*
Aster ciliolatus	Ciliolate aster
Aster macrophyllus	Large-leaved aster
Circaea alpina	Smaller enchanter's nightshade
Clintonia borealis	Bluebead-lily
Convolvulus arvensis	Field bindweed
Coptis trifolia	Goldthread
Epilobium angustifolium	Fireweed
Fragaria virginiana ssp. *virginiana*	Scarlet strawberry – Wild strawberry*
Galium triflorum	Fragrant bedstraw
Geocaulon lividum	Northern comandra
Goodyera repens	Dwarf rattlesnake-plantain
Maianthemum canadense	Wild lily-of-the-valley
Maianthemum trifolium	Three-leaved solomon's seal – Three-leaved smilacina*
Mertensia paniculata	Northern bluebells
Mitella nuda	Naked mitrewort
Monotropa uniflora	Indian-pipe
Oxalis acetosella ssp. *montana*	True wood-sorrel
Oxalis stricta	Upright yellow wood-sorrel
Petasites frigidus	Palmate-leaf sweet-coltsfoot – Sweet coltsfoot*
Pyrola spp.	Pyrolas
Solidago rugosa ssp. *rugosa*	Rough goldenrod
Streptopus amplexifolius	Clasping-leaved twisted-stalk – White mandarin*
Streptopus roseus	Rose twisted-stalk
Taraxacum officinale	Common dandelion
Trientalis borealis ssp. *borealis*	Star-flower
Trillium cernuum	Nodding trillium
Viola renifolia	Kidney-leaved violet
Viola spp.	Violets

Ferns

Athyrium filix-femina var. *angustum*	Northern lady fern
Botrychium virginianum	Rattlesnake fern
Dryopteris carthusiana	Spinulose wood fern – Spinulose shield fern*
Gymnocarpium dryopteris	Oak fern
Pteridium aquilinum var. latiusculum	Eastern bracken-fern – Bracken fern*

Horsetails

Equisetum arvense	Field horsetail
Equisetum sylvaticum	Wood horsetail – Woodland horsetail*

Club-mosses

Huperzia lucidula	Shining club-moss
Lycopodium annotinum	Bristly club-moss – Interrupted clubmoss*
Lycopodium clavatum	Running club-moss – Wolf's claw clubmoss*
Lycopodium obscurum	Ground pine
Lycopodium spp.	Club-mosses

Grasses and Sedges

Calamagrostis canadensis	Canada blue-joint
Carex spp.	Sedges
Cinna latifolia	Broad-leaved reed grass
Oryzopsis asperifolia	White-grained mountain-rice – Mountain rice grass*

Mosses and Liverworts

Bazzania trilobata	Three-lobed bazzania
Brachythecium spp.	
Calliergon spp.	
Climacium dendroides	Northern tree moss
Dicranum flagellare	Spiky dicranum moss
Dicranum fuscescens var. *fuscescens*	Curly heron's-bill moss
Dicranum montanum	Lawn moss
Dicranum polysetum	Wavy-leaved moss
Dicranum scoparium	Broom moss
Hylocomium splendens	Stair-step moss

Hypnum pallescens var. *pallescens*	Stump pigtail moss
Jamesoniella autumnalis var. *autumnalis*	Jameson's liverwort
Mnium spp.	
Plagiomnium cuspidatum	Woodsy mnium moss
Plagiothecium laetum	Glossy moss
Plagiothecium spp.	
Pleurozium schreberi	Schreber's moss
Polytrichum commune var. commune	Common haircap moss
Polytrichum juniperinum	Juniper haircap moss
Ptilidium ciliare	Northern naugehyde liverwort
Ptilidium pulcherrimum	Naugehyde liverwort
Ptilium crista-castrensis	Feather moss – Plume moss*
Rhizomnium pseudopunctatum	
Rhytidiadelphus triquetrus	Electrified cat-tail moss
Sanionia uncinata	Sickle moss
Sphagnum angustifolium	(Yellow two-leaved peat moss)
Sphagnum capillifolium	(Lady's tresses peat moss)
Sphagnum fuscum	(Brown bog peat moss)
Sphagnum girgensohnii	(Common green peat moss)
Sphagnum magellanicum	(Red fat-leaved peat moss)
Sphagnum wulfianum	Wulf's peat moss
Tetraphis pellucida	Common four-tooth moss
Thuidium delicatulum	Common fern moss
Tomenthypnum nitens	Fuzzy brown moss – Ribbed bog moss*

Names in brackets are translated from Finnish and may be useful as memory aids.

Lichens

Cladina mitis	Yellow-green lichen
Cladina rangiferina	Reindeer lichen
Cladina stellaris var. *stellaris*	Coral lichen
Cladonia chlorophaea	False pixie cup lichen
Cladonia coniocraea	Powder horn lichen
Cladonia cristatella	British soldiers

Insects

Agrilus anxius	Bronze birch borer
Bucculatrix canadensisella	Birch skeletonizer
Choristoneura conflictana	Large aspen tortrix
Choristoneura fumiferana	Eastern spruce budworm
Choristoneura pinus pinus	Jack pine budworm
Dendroctonus rufipennis	Spruce beetle
Malacosoma disstria	Forest tent caterpillar
Pikonema alaskensis	Yellowheaded spruce sawfly
Pissodes strobi	White pine weevil
Saperda calcarata	Poplar borer

Fungi

Armilliaria spp.	Armillaria root rot
Armilliaria sinapina	Armillaria root rot
Armilliaria ostoyae	Armillaria root rot
Entoleuca mammata (Hypoxylon mammatum)	Hypoxylon canker
Inonotus tomentosus (Polyporus tomentosis)	Tomentosus root rot
Phellinus pini	Red ring rot
Phellinus tremulae	Stringy white rot
Stereum sanguinolentum	Red heart rot
Venturia macularis	Shoot blight of aspen

Mammals

Alces alces	Moose
Glaucomys sabrinus	Northern flying squirrel
Lepus americanus	Snowshoe hare
Lynx canadensis	Canada Lynx
Martes americana	Marten
Odocoileus virginianus	White-tailed deer
Peromyscus maniculatus	Deer Mouse
Rangifer tarandus	Caribou
Ursus americanus	Black bear

Birds

Bonasa umbellus	Ruffed grouse
Dendroica castanea	Bay-breasted warbler
Dryocopus pileatus	Pileated woodpecker
Empidonax minimus	Least flycatcher
Falcipennis canadensis	Spruce grouse
Picoides arcticus	Black-backed woodpecker
Poecile hudsonicus	Boreal chickadee
Regulus calendula	Ruby-crowned kinglet
Strix nebulosa	Great gray owl
Zonotrichia albicollis	White-throated sparrow

Amphibians

Ambystoma laterale	Blue-spotted salamander

* Nomenclature for plant species (Latin and first listed common names) based on Newmaster *et al.* 1998. Other listed common names are based on frequently used regional names.

Nomenclature for insects (Latin and common names) based on Benoit 1985.

Nomenclature for fungi (Latin and common names) based on Berube and Dessureault 1998, Farr *et al.*1989, Rogers and Ju 1996.

Nomenclature for mammals (Latin and common names) based on Dobbyn 1994.

Nomenclature for birds (Latin and common names) based on American Ornathologist Union 1998.

Nomenclature for amphibians (Latin and common names) based on Cook 1984.

GLOSSARY

advance growth

see advance regeneration

advance regeneration

Young trees under existing stands capable of becoming the next crop. Regeneration established before logging that has survived the logging operation. (NRC 1995).

aerial seed bank

see seed bank

age class

A distinct group of trees or portion of growing stock recognized on the basis of age (NRC 1995).

all-aged

Of a forest, crop, or stand that contains trees of all, or almost all age classes, including those of exploitable age (NRC 1995).

apical dominance

A phenomenon in most higher plants whereby the growing apical bud inhibits, to varying degrees, the growth of lateral (axillary) buds (Taiz and Zeiger 1991).

artificial regeneration

The establishment of a tree crop by direct seeding or planting seedlings or cuttings (NRC 1995).

autecology

The study of environmental factors and their effects on individual plants (adapted Barnes *et al.* 1998).

auxin

A plant hormone having a wide variety of effects on plant growth and morphogenesis, including the promotion of cell division in stems and the inhibition of cell division in lateral buds (adapted Taiz and Zeiger 1991).

available nutrient

That portion of any element or compound in the soil that can be readily absorbed and assimilated by growing plants (Brady and Weil 1999).

band application

Applying pesticides and/or fertilizers in a linear strip on or along crop rows rather than over the entire ground area (NRC 1995).

bareroot stock

Seedlings that are planted with their roots bare of soil (NRC 1995).

barren and scattered

Productive forest land which, because of natural or artificial disturbance, contains only scattered trees or no trees at all with either shrub cover or bare soil, but no significant amount of regeneration (adapted NRC 1995).

basal bark treatment

A treatment for killing trees and brush in which a herbicide is applied, by sprayer or brush, to a band of bark encircling the basal portion of the stem (NRC 1995).

basal injection

A treatment consisting of forcing a liquid or an encapsulated herbicide into the basal portion of a tree (NRC 1995).

binding

A form of manual site preparation or tending where stems are bound together to suppress non-crop (particularly mountain maple) vegetative competition.

biodiversity

Variation in the biotic community. Used synonymously with the term biological diversity. There are many measures of biodiversity: genetic diversity, local species richness and evenness, and local diversity in community structure (alpha diversity); variation in species richness and community structure across the local landscape (beta diversity); and changes over time in these measures of biodiversity (temporal diversity). All of these measures can occur within one landscape unit. Landscape (physical or ecological) diversity provides a framework for regional biodiversity (gamma diversity) (Kimmins 1997).

biological control

A cleaning method that involves the use of naturally occurring fungi, bacteria, viruses or herbivorous insects, or phyotoxins to suppress or reduce plant populations (Wagner *et al.* 2001).

biological legacy

A tree, downed log, snag, or other components of the forest stand left after a stand-initiating disturbance (Franklin *et al.* 1997). Includes reproductive structures of various crop and competitive species on a site after disturbance.

blading

Using the straight blade of a crawler tractor or similar equipment to remove coarse woody debris and thick duff off the site to create planting (or seeding) spots (NRC 1995).

block cutting

Removal of the crop in blocks in one or more operations, generally for wildlife management purposes, encouraging regeneration, or protecting fragile sites (NRC 1995). A spatial variation of the conventional clearcut harvest method.

blowdown

see windfall

boreal mixedwood site

A boreal mixedwood site is an area with climatic, topographic, and edaphic conditions that favour the production of closed canopies dominated by trembling aspen or white birch in early successional stages, black spruce or white spruce in mid-successional stages, and balsam fir in late successional stages. Boreal mixedwood sites have a moisture regime in the range two to five (adapted MacDonald and Weingartner 1995).

boreal mixedwood stand

A boreal mixedwood stand is a tree community on a boreal mixedwood site in which no single species exceeds 80 percent of the basal area (MacDonald and Weingartner 1995).

broadcast application

Applying pesticides and/or fertilizers with relative uniformity over the entire ground area (NRC 1995).

broad soil group

For the purpose of this guide, broad soil groups are groupings of soil textures that are believed to respond consistently to silvicultural intervention.

canker

A depressed area on a tree stem that results from lack of stem enlargement in a diseased area (canker fungi cause death of a localized stem area, thereby interrupting the production and maintenance of functional phloem) (adapted Manion 1991).

canopy (canopy layer)

The more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees (NRC 1995).

canopy closure

1. The progressive reduction of space between crowns as they spread laterally, increasing canopy density.
2. The point in time when crowns in a young stand begin to touch and interact (NRC 1995).

canopy transition stage

The stage of stand development immediately following the stem exclusion stage, when intense competition among stems comes to an end. As canopy trees start to decline and die because of longevity or damage from non-stand-replacing disturbances, shade tolerant coniferous trees from the understorey and intermediate canopy (where present) take over the main canopy. New individuals can also be established in gaps created by tree mortality. Structural characteristics of this stage include canopy gaps as well as a potentially stratified canopy. This stage of stand development ends when all of the individuals from the initial cohort have died (adapted Chen and Popadiouk 2002).

claybelt

A large physiographic region located within northeastern Ontario and northwestern Québec (approximately 1,250,000 km^2). Topography is nearly level; the claybelt features vast lowlands of poorly drained clay soils, the result of lacustrine deposits from glacial Lake Barlow-Ojibway. The poor drainage together with the cold, wet climate has resulted in the development of organic soils that cover a large portion of the region (adapted Lefort *et al.* 2002).

cleaning

An operation to free favoured trees from undesirable individuals of similar age or size which overtop them or are likely to do so (adapted OMNR 1996).

clearcut

Area harvested under the clearcut silvicultural system (OMNR 1996).

clearcut system

A silvicultural system that typically involves the regeneration of an even-aged forest stand in which new seedlings become established in fully exposed microclimates after most or all of the existing trees have been removed. Regeneration can originate naturally or artificially. Associated harvest methods include conventional clearcut, clearcut with standards, seed tree, and two-stage. Clearcutting may be done in blocks, strips, or patches (adapted OMNR 1996).

clearcut with standards

A clearcut harvest method that involves the removal of all but a few mature aspen stems from throughout an aspen dominated or aspen leading stand in an attempt to reduce aspen suckering.

clone

All plants reproduced asexually from a common ancestor and having identical genotypes.

closed canopy

see canopy closure

cluster planting

Planting clusters of spruce with natural regeneration of hardwoods in the areas around the clusters. A hardwood-free zone is maintained around each cluster to maximize spruce growth (BCMoF 2000).

coarse woody debris

The standing and downed dead wood in a forest (NRC 1995).

co-dominant crown class

see crown class: co-dominant

cohort

An aggregation of trees that starts as a result of a single disturbance (Smith *et al.* 1997).

commercial thinning

see thinning: commercial

community

The assemblage of living organisms (plants, animals, microbes) that interact with each other in energy flow and nutrient cycling processes in an ecosystem. The biotic component of a particular ecosystem (Kimmins 1997).

competition

A process that occurs when two different species attempt to utilize the same resource when that resource is in limited supply (Kimmins 1997).

composition

The proportion of each tree species in a stand expressed as a percentage of the total number, basal area, or volume of all tree species in the stand (NRC 1995).

competition threshold

The level of vegetation abundance where there is an abrupt increase or decrease in the rate of change in tree growth or survival (Wagner *et al.* 1989).

compositional treatment

Alteration of overstorey stand species composition to meet compositional and/or structural objectives. Site occupancy must be maintained.

coppice

Natural regeneration originating from stump sprouts, stool shoots, or root suckers (NRC 1995).

cover crop

A suitable herbaceous crop grown to reduce erosion, increase soil fertility, reduce invasion of more competitive vegetation, provide wildlife habitat, or protect a site; it can be dug or ploughed-in while succulent, with or without supplementary fertilizers (NRC 1995).

crop rotation

A planned sequence of crops growing in a regularly recurring succession on the same area of land, as contrasted to continuous culture of one crop or growing different crops in a haphazard order (Brady and Weil 1999).

crop tree

Any tree selected to become or forming a component of the final crop (NRC 1995).

crown

The part of a tree bearing live branches and foliage (Hayden *et al.* 1995).

crown class

A coding system that defines the crown position of an individual tree (Hayden *et al.* 1995).

emergent

When the tree crown extends well above the general level of the crown layer and receives full light from above and from the sides. A tree in this class is much larger than the neighbouring trees and has a more fully developed crown (Hayden *et al.* 1995).

dominant

When the tree crown extends above the general level of the crown layer and receives full light from above and partial light from the side (Hayden *et al.* 1995).

co-dominant

When the tree crown forms a part of the general level of the crown layer and receives full light from above but little light from the sides. This class applies when two or more trees of equal size are adjacent to one another (Hayden *et al.* 1995).

intermediate

When a tree that is shorter than its neighbours has a crown that extends into the neighbouring trees and receives direct light from above but not from the side. Trees in this class usually have small crowns on the side (Hayden *et al.* 1995).

overtopped/suppressed

When the tree crown is entirely below the general level of the crown layer and receives no direct light either from above or from the sides. Trees in this class normally display restricted height growth and may have elongated lateral branches, leaning terminal growth, or flat-topping (Hayden *et al.* 1995).

understorey

A general term used to describe a layer of trees developing under an overstorey.

open understorey

When a tree previously classified as overtopped/suppressed, or understorey has been released due to stand breakup, windthrow, etc. Trees in this class receive full light from the top and sides. This category includes trees growing where no trees have grown before (Hayden *et al.* 1995).

crown closure

The available crown space between trees; 100 percent crown closure is the time at which all available crown space is fully occupied (NRC 1995).

crown cover

The ground area covered by the crowns of trees or woody vegetation as delineated by the vertical projection of crown perimeters and commonly expressed as a percentage of total ground area (NRC 1995).

crown fire

Rapidly moving fire burning through the crowns of woody vegetation, frequently leaving stems and much of the forest floor relatively untouched (Kimmins 1997).

cull

Trees or logs or portions thereof that are of merchantable size but are rendered unmerchantable by defects (NRC 1995).

cutover

An area of forest land from which some or all timber has recently been cut (NRC 1995).

cut-stump treatment

see stump treatment

dieback

Used to describe a category of diseases caused by an interacting set of factors (more than one agent). Also called decline (Hayden *et al.* 1995).

direct seeding

see seeding: direct

dominant crown class (dominance)

see crown class: dominant

downed woody debris

The downed dead wood in a forest (NRC 1995).

ecodistrict

Ecodistricts lie within ecoregions and are delineated based on their differing surficial geology while sharing broad microclimate features with ecoregions they occur within. They occur at a scale of 1:250,000 to 1:500,000 and are used for strategic planning at sub-regional levels, watershed planning, and for policy (Taylor *et al.* 2000).

ecological land classification (ELC)

A hierarchical approach to classifying land which is based on a consistent framework of landscape and site-level ecosystems by combinations of geologic, climatic, vegetative, soil, and landform features (OMNR 1996).

ecoregion

An ecological landscape unit representing land areas of tens of thousands of square kilometres characterized by distinct patterns of responses to climate as expressed by soils, hydrology, vegetation (species ranges and productivity), and fauna (OMNR 1996). Ecoregions lie within ecozones, thus sharing a common bedrock geology. (Crins and Gray, in prep.).

ecosite (synonyms: general standard site types, site type)

An ecological landscape unit (ranging in resolution from hundreds to thousands of hectares) comprised of relatively uniform geology, parent materials, soils, topography, and hydrology, occupied by a consistent complex of successionally related vegetation conditions (OMNR 1996).

northeast ecosite

Ecosites are mappable, management-oriented groupings of vegetation on specific ranges of soil conditions. Ecosites occur at spatial scales ranging from 1:10,000 to 1:50,000. Ecosites have relatively uniform parent material, soils, hydrology and vegetation structure, and composition. A single ecosite may be comprised of a number of vegetation types and soil types. The mapping scales associated with ecosites are appropriate for forest management prescriptions (Taylor *et al.* 2000).

northwest ecosite

The ecosite is primarily a mapping unit integrating a consistent set of environmental factors and vegetation conditions. Ecosites are composed of ecoelements that describe common assemblages of both abiotic (soil depth, texture, moisture regime, hydrology, and nutrient regime) and biotic (plant community structure and composition) components. Mapped ecosites may vary in size from a normal minimum polygon size of five to eight hectares to hundreds of hectares. Appropriate mapping scales vary from 1:10,000 to 1:50,000 (Racey *et al.* 1996).

edge effects

Environmental, biological, and anthropogenic factors occurring within the ecotone between two habitat types. In a forested landscape, edge effects may extend from disturbed habitat into undisturbed habitat, making it less suitable for species adapted to interior stand conditions but more suitable for "edge loving" species (OMNR 2001b).

emergent crown class

see crown class: emergent

establishment

The process of developing a crop to the stage at which the young trees may be considered established, i.e. safe from juvenile mortality and no longer in need of special protection or special tending and only routine cleaning, thinning, and pruning (NRC 1995).

establishment period

The time elapsing between the initiation of a new crop and its establishment (NRC 1995).

even-aged management

Silvicultural systems in which stands have an even-aged structure (e.g. clearcut and shelterwood systems) (OMNR 1996).

even-aged structure

A forest, stand, or forest type in which relatively small age differences exist between individual trees. The difference in age is usually 10 to 20 years; if the stand will not be harvested until it is 100 to 200 years old, larger differences up to 25 percent of the rotation age may be allowed (OMNR 1996).

exposed

see open-grown

fill planting

The planting of trees in areas of inadequate stocking to achieve the desired level of stocking, either in plantations or areas of natural regeneration (NRC 1995).

fire cycle

The normal length of time between fire events for different types of forest (OMNR 2001b).

fire intensity

The length of the flame or amount of energy generated (Barnes *et al.* 1998).

fire regime

The kind(s) of fire and the prominent immediate effects of fire that characterize an area. A fire regime is typically characterized by the following features: type, frequency, intensity, severity, size, and timing (season of burning).

fire severity

The effect of fire on the soil or the vegetation (seedbank, mortality of plants) (Barnes *et al.* 1998).

fire return interval

The average number of years between successive fires; may be expressed for a given point or for an area (Barnes *et al.* 1998).

forest ecosystem

An ecosystem dominated by trees in which the microclimate, soils, hydrology, nutrient cycling, biomass creation, storage and turnover, and food chain processes reflect the dominance by large, long-lived woody plants (Kimmins 1997).

forest ecosystem classification (FEC)

A system used to classify ecological conditions in the Central, Northeast, and Northwest regions of OMNR (Hayden *et al.* 1995).

forest management plan

A document containing pertinent information and prescriptions by means of which forest policy, aims, and objectives are translated into a continuity of specific treatments on a management unit for a specified period of years (OMNR 1996).

forest operations prescription

A site specific, integrated set of harvest, renewal, and maintenance activities that is developed before any operations can commence in a particular stand (OMNR 2001c).

forest resource inventory (FRI)

A resource inventory conducted for each management unit on average every 20 years. The FRI divides the area into a number of components, such as water, non-forested, non-productive forest, and productive forest; and further classifies each component by ownership/land use categories. The FRI provides descriptive information about the timber resource on each management unit (e.g. stand age, stand height, species composition, stocking level) in the form of interpreted aerial photographs, forest stand maps, and a set of standard inventory ledgers referred to as reports (OMNR 1996).

forest stand dynamics

The study of changes in forest stand structure with time, including stand behaviour during and after disturbance (Oliver and Larson 1996).

forest unit

Forest units are aggregations of forest stands which normally have similar species composition, develop in a similar manner (both naturally and in response to silvicultural treatments), and are managed under the same silvicultural system. In Ontario, determination of forest units is based on considerations such as site, economics, and product requirements (OMNR 1996).

free-to-grow

Stands that meet stocking, height, and/or height growth rate, as specified in the ground rules and are judged to be essentially free from competing vegetation (OMNR 1996).

full-tree logging

The removal of the whole tree to the roadside where limbing and topping occurs (OMNR 1997c).

fully stocked

Productive forest land stocked with trees of merchantable species. These trees by number and distribution or by average dbh, basal area, or volume are such that at rotation age they will produce a timber stand that occupies the potentially productive ground. They will provide a merchantable timber yield according to the potential of the land. The stocking, number of trees, and distribution required to achieve this will be determined from regional or local yield tables or by some other appropriate method (NRC 1995).

gap dynamics stage

The stage of stand development immediately following the canopy transition stage. Trees established through self-perpetuation dominate the stand. Growing space is available in all strata because of the death of individual trees or groups of trees. This stage is structurally characterized by a mosaic canopy, generally dominated by shade-tolerant species, usually spruce and fir. Gaps are occupied by shade-intolerant and (or) shade-tolerant trees and (or) shrubs such as mountain maple, beaked hazel, speckled alder, raspberries, and willows, depending on local site conditions (Chen and Popadiouk 2002).

general standard site type (synonyms: ecosite, site type)

A coding or labelling system in the silvicultural guide to allow for referencing of site description information on similar sites across the province. Regional ecosites are the working units of General Standard Site Types (OMNR 1996).

genetic diversity

The amount of genotypic variation in a population (Maynard 1996).

genetic gain

The difference in the performance of offspring derived from selected parents and the average performance of the original, unselected parental population (OMNR 1987).

girdling

Making more or less continuous incisions around a living stem, through at least both bark and cambium, generally with the object of killing the tree. Sometimes termed mechanical girdling, to distinguish it from herbicide girdling when herbicide is added. Making a series of close downward and upward, i.e. V-shaped, incisions into the sapwood is termed notch-girdling.

Also applies to the destruction of tissue, particularly living tissue, by insects, rodents, etc., in a rough ring around a stem, branch, or root (after NRC 1995).

granular application

A general process by which fertilizers or herbicides in the form of grains are applied to a given area (NRC 1995).

green striping

Band application of herbicides at the stand initiation stage to remove overtopping and lateral non-crop vegetation surrounding planted conifers.

group selection method

A method of regenerating and maintaining uneven-aged stands in which trees are removed in small groups (NRC 1995).

high-grading

A partial harvest removing only the most valuable species or trees of desirable size and quality, without regard for the condition of the residual stand (NRC 1995).

high (crown) thinning

see thinning: high crown thinning

humus form

A soil classification for the upper organic horizons of a soil (Hayden *et al.* 1995).

moder

A forest floor type in which there is a distinct litter (L) and decomposing (F) layer, and a humus (H) layer that grades into and is partly mixed with the underlying mineral soil (i.e. there is an Ah layer). Unlike a mor forest floor, the F layer is loose and friable, with little matting caused by fine roots and fungal mycelia, and it often has abundant soil animal activity. The Ah layer is less than 10 centimetres thick (Kimmins 1997).

mor

A forest floor type in which there are distinct litter (L), decomposing (F), and humus (F) layers, and a sharp transition between the organic forest floor and the underlying mineral soil. Dominated by fungi and having little or no animal mixing, the F layer is densely matted with fine roots and fungal mycelium. Generally acidic. Characteristic of sites with slow decomposition of litter and low fertility (Kimmins 1997).

mull

A forest floor type in which there is a thin layer of fresh or recent litter (L layer), virtually no F layer, and an Ah layer (a surface mineral soil horizon enriched with organic matter) that grades slowly into the underlying mineral soil. The Ah layer is more than 10 centimetres thick. Associated with productive, moist, and fertile sites, and abundant soil animal activity that mixes the organic forest floor material with the upper mineral soil (zooenous Ah; rhizogenous Ah horizons can be formed by rapid turnover of fine roots in the upper mineral soil). Also characteristic of grassland soils (Kimmins 1997).

inbreeding

Producing offspring from the mating of relatives (OMNR 1987).

insular residual patches

Living internal patches, consisting of distinct islands greater than 0.25 hectares, retained on clearcut areas to provide vertical forest structure, relic patches of old growth, wildlife habitat and future sources of downed woody debris (OMNR 2001b).

intermediate crown class

see crown class: intermediate

intermediate stand treatment (synonym: tending)

Any treatment in a stand during that portion of the rotation not included in the final harvest or regeneration period (NRC 1995).

juvenile spacing

The espacement of crop trees at the stand initiation stage.

layering

The rooting of an undetached branch that is lying on or partially buried in the soil and is capable of independent growth after separation from the parent plant (Hayden *et al.* 1995).

leave strip

A strip of timber left standing between two clearcut areas (NRC 1995).

liberation treatment

The release of young trees, not past the sapling stage, from the competition of distinctly older, overtopping trees (Smith 1997).

live crown ratio

A rough but convenient index of the ability of the crown of a tree to nourish the remaining part of the tree; it is the percentage of length of stem having living branches (NRC 1995).

logging method

A term which indicates the process used to move wood products from stump to roadside during a harvesting operation. Types of logging methods include full-tree, tree-length, and shortwood (OMNR 1996).

low thinning

see thinning: low thinning

mechanical thinning

see thinning; mechanical thinning

merchantable

A tree or stand that has attained sufficient size, quality, and/or volume to make it suitable for harvesting. Does not imply accessibility, economic or otherwise (NRC 1995).

multiple-cohort stand

see uneven-aged stand

natural regeneration

Renewal of a tree crop by natural seeding, sprouting, suckering, or layering (OMNR 1996).

natural selection

Natural elimination of individuals on the basis of their phenotypic inability to survive or produce offspring under a particular set of environmental conditions (Wright 1976).

nutrient cycling

The continual, cyclic exchange of chemicals (nutrients) between the biota and the physical environment within an ecosystem (Kimmins 1997).

open-grown (synonym. exposed)

Trees with crowns receiving full light from all sides due to the openness of the canopy (NRC 1995).

open-pollinated

Pollination occurring due to wind or insects (Maynard 1996).

open understorey crown class

see crown class: open understorey

overmature

In even-aged management, those trees or stands past the mature stage (OMNR 1996).

overstorey removal

A final harvest in which the cutting releases advance regeneration (NRC 1995).

overstorey retention

The enhanced retention of a portion of the overstorey when the primary objective is the promotion of an uneven-aged stand with maximum vertical and horizontal structure (Franklin *et al.* 1997). Overstorey retention is applicable with the shelterwood and selection systems. Retention level depends on diversity objectives.

overtopped/suppressed crown class

see crown class: overtopped/suppressed

paludification

Formation of mire systems (e.g. bogs and fens) over previously forested land, grassland, or even bare rock, due to climatic or autogenic processes. The literal meaning is "swamping" (adapted Gore 1983).

partial canopy retention

Retention of selected trees in a stand.

partial harvest

Any cutting in which only part of the stand is harvested (NRC 1995).

patch cutting

The removal of stands in an irregularly shaped, spaced, and sized cut area (OMNR 1997c). A spatial variation of the conventional clearcut harvest method.

pathogen

A microscopic organism or virus directly capable of causing disease (NRC 1995).

peninsular residual patches

Portions of live peninsular patches connected to harvest block perimeters of clearcut areas that are retained to provide vertical forest structure, relic patches of old growth, wildlife habitat, and future sources of downed woody debris (OMNR 2001b).

percent cover

The percentage of the ground area covered by a vertical projection of the crown of the plant over the ground (Hayden *et al.* 1995).

phenotype

The appearance of an individual; a composite of the genotype and the environment and their interaction (OMNR 1997).

pioneer species

A species adapted to the early stage of natural forest succession or growth on newly available sites (NRC 1995).

post gap-phase (shrubland)

see barren and scattered

pre-commercial thinning

see thinning: pre-commercial

pre-harvest silviculture prescription

A site-specific, integrated plan developed prior to cut block layout. These plans incorporate many site-related factors and detail specific measures for achieving resource management objectives. These prescriptions allow resource managers to develop and apply forest management practices that are more ecologically appropriate (Bidwell *et al.* 1996). A pre-harvest assessment may be used to gather the information necessary to develop the prescription.

pre-harvest treatment

Any appropriate treatment directed at establishing a new crop before final felling of the existing stand.

prescribed burn

The knowledgeable application of fire to a specific land area to accomplish predetermined forest management or other land management objectives (OMNR 1996).

primary succession

Successional development of an ecosystem beginning after a disturbance that has removed all of the modifications to microclimate and the geological substrate produced by the previous succession. Succession on bare rock, in shallow lakes, or on parent soil materials (Kimmins 1997).

productive forest land

All forest areas which are capable of growing commercial trees, irrespective of planning decisions, and which are further sub-divided into "protection forest" and "production forest." (OMNR 1996).

propagation

see vegetative reproduction

protection of advance growth

An operational practice where advance growth less than 10 centimetres dbh is protected during the removal of the main canopy.

provenance

The original geographic sources of seed, pollen, or propagules (OMNR 1987).

pruning

1. The removal of live branches from standing trees (green pruning) or of dead branches (dry pruning).
2. Removal of live or dead branches from ground level to as high as a person's reach (2.0 to 2.5 metres) in a young stand, known as brashing; above a person's reach (e.g. with a ladder), high pruning. If only crop trees are high pruned, the operation is called selective high pruning. Pruning or lopping that increases the clearance under a tree is sometimes termed lifting the canopy (NRC 1995).

pure species stand

A stand in which a single tree species comprises more than 80 percent of the total basal area.

regeneration

The establishment of a tree crop by natural (self-sown seed or by vegetative means) or artificial means (direct seeding and planting). Regeneration may also be used to describe the young crop itself (OMNR 1996).

reinitiation

Removal of most or all stems in a regenerating stand and the application of silvicultural treatments to establish a healthy and productive forest community which will meet the planned future forest condition.

release

Freeing a tree or group of trees from more immediate competition by cutting or otherwise eliminating growth that is overtopping or closely surrounding them (NRC 1995).

renewal

Silvicultural operations undertaken to promote the establishment of desired future forest stands. Forest renewal usually includes the activities of site preparation and regeneration (OMNR 1996).

reproduction method

The procedure by which a stand is established or renewed, including removal of the existing stand and establishment of the new one (Smith *et al.* 1997).

residual tree

Individual living trees or snags retained on a site (OMNR 2001a).

rhizome

A horizontal stem that bears roots and leafy shoots (OMNR 1997c).

rotation

The planned number of years between the formation or regeneration of a crop or stand and its final cutting at a specified stage or maturity (NRC 1995).

rutting

The creation of trenches or furrows in the ground by breaking through the forest floor (slash, litter, and humus layers) and compacting or displacing mineral or organic soil. Ruts are the result of having exerted ground pressures in excess of the weight-bearing capacity of the soil. They are normally associated with the use of heavy wheeled or tracked logging equipment (Archibald *et al.* 1997).

sapling

A general term for a young tree no longer a seedling but not yet a pole, about 1 to 2 metres high and 2 to 4 centimetres in dbh, typically growing vigorously and without dead bark on more than an occasional dead branch. Also, a young tree having a dbh greater than 1 centimetre but less than the smallest merchantable diameter (NRC 1995).

satisfactorily stocked

Productive forest land that has been regenerated naturally or artificially to at least a minimum number of well-established, healthy trees of merchantable species that are free from noncrop competition and sufficient to produce a merchantable timber at rotation age (NRC 1995).

S-type

see soil type

scarification

Loosening the topsoil of open areas or breaking up the forest floor to assist the germination of natural seed from either standing trees or slash or to promote the occurrence of coppice or sucker growth (NRC 1995).

seed bank

The assemblage of viable but ungerminated seeds present in the soil, or held in closed cones in the canopy, which will germinate if the present vegetation is killed or removed (Kimmins 1997).

seed tree

A tree selected, and often reserved, for seed collection or provision of seed for natural regeneration (NRC 1995).

seed tree harvest method

A method of harvesting and regenerating a forest stand in which all trees are removed from the area except for a small number of seed-bearing trees that are left singly or in small groups or strips for regeneration purposes. The objective is to create an even-aged stand (OMNR 1996).

seed year

In Ontario, a year when 75 to 100 percent of the trees have a seed crop that exceeds more than half of the maximum yield per tree (OMNR 1977).

seed zone

An area within which seed can be collected from any natural stand and planted in any new site without fear of mal-adaptation (Maynard 1996).

seedbed

natural regeneration

The soil or forest floor on which seed falls.

nursery practice and in the field

A prepared area over which seed is sown (NRC 1995).

seeding – direct

The sowing of seeds by manual or mechanical means (NRC 1995). Direct seeding can include:

broadcast seeding

The sowing of seeds more or less evenly over a whole area on which a forest stand is to be established (NRC 1995).

precision seeding

The systematic sowing of seeds by manual or mechanical means in an area on which a forest stand is to be grown (OMNR 1997c).

spot seeding

Precision seeding in small, prepared patches throughout a site (NRC 1995).

drill seeding

Precision seeding in shallow furrows across a site (NRC 1995).

seeding – natural

The dispersal by natural agents of seeds from standing trees or from cone-bearing slash. Seeds may be dispersed by wind, birds, mammals, gravity, or flowing water or be released by fire from serotinous cones (NRC 1995).

seedling

A young tree, grown from seed, from the time of germination to the sapling stage, having a dbh of no more than 1 centimetre and a height of no more than 1.5 metres (NRC 1995).

selection system

An uneven-aged silvicultural system where mature and/or undesirable trees are removed individually or in small groups over the whole area, usually in the course of a cutting cycle. Regeneration is generally natural (OMNR 1996).

self-pruning

The inherent ability of a tree species to shed dead branches at their junction with the live stem (NRC 1995).

self-thinning

Tree mortality from the effect of the competition arising between trees on the same site (NRC 1995).

sensitive sites

Those sites which have a high probability of one or more types of damage (e.g. rutting or errosion) occurring if managed according to standard operating practices (after Archibald *et al.* 1997).

seral stage

The identifiable stages in the development of a sere, from an early pioneer stage, through various early and mid-seral stages, to seral, subclimax, and climax stages. The stages are identified by different plant associations (different species composition and/or community structure), different stages of the dominant vegetation (usually related to differences in structure), and by different microclimatic, soil, and stand condition (Kimmins 1997).

shade tolerance (tolerant)

The ability of a plant to germinate, establish, survive, compete for resources, and grow in the shade of other plants. A complex characteristic of plants involving seed size, physiological and morphological adaptations to low light intensity, root-shoot ratios, disease resistance, and the ability to compete for soil resources at low light levels. Shade tolerance of trees often varies with their age. Shade-tolerant tree species often grow best in full sunlight or very light shade (Kimmins 1997).

shortwood (cut-to-length) logging

The limbing, topping, and cutting to length of trees at the stump, followed by removal of the logs to roadside (Richardson and Makkonen 1994).

silvicultural ground rule

A description of the current forest condition, the desired future forest condition, and the silvicultural treatment package that the forest manager expects to follow in order to attain the desired outcome. It also includes the standards that must be met for a stand to be considered successfully regenerated or managed, and developing in a way that will permit it to attain the desired forest conditions (OMNR 2001c)

silvicultural system

A planned program of silvicultural treatments that extends throughout the life of a stand for the purpose of controlling stand establishment, composition and growth, and includes a reproduction method as well as any tending and intermediate stand treatments (Smith *et al.* 1997).

silvicultural treatment

An activity, whether biological or managerial, through which a forest operations prescription is met (OMNR 1996).

silvicultural treatment package

The range of acceptable treatments (harvest, renewal, tending) for the appropriate forest unit and site type combination which can be undertaken at various intervals throughout the life of a forest stand to achieve the desired future stand condition (OMNR 1996).

silviculture

The scientific, creative, and practical use of silvics at the site level to control species establishment, composition, growth, and stand structure (Smith *et al.* 1997).

site preparation

The disturbance of the forest floor and upper soil horizons (and/or vegetation) to create suitable conditions for regeneration through the use of manual or motor-manual techniques, mechanical equipment, chemical (herbicide) application, prescribed burning, or a combination of these approaches (after OMNR 1996).

Mechanical site preparation methods include (Sutherland and Foreman 1995):

screefing

The removal or displacement of the organic layer to expose or scarify the underlying mineral soil. Includes blading, shearblading, scalping, and raking.

inverting

Flipping over parts of the forest floor organic layer, with or without the underlying mineral soil, onto the adjacent undisturbed forest floor.

mounding

The creation of raised planting spots.

trenching

Removing and mixing of both the mineral soil and organic layers into berms on top of the adjacent, undisturbed forest floor.

mixing

Incorporation of the organic layer and fine debris into the underlying mineral soil.

Chemical site preparation methods include:

broadcast spraying

Chemical treatment of an entire block using aerial or ground-based equipment.

band spraying

Aerial or ground application of herbicide in bands of predetermined width.

ground selective application

Chemical treatment of individual targeted stems or a small specific area using ground-based equipment.

site quality

The productive capacity of a site; usually expressed as volume production of a given species per unit area (cubic metres per hectare) or per unit of time (cubic metres per year) (NRC 1995).

site type (synonyms: ecosite, general standard site type)

see ecosite, general standard site type

slenderness coefficient

Ratio of tree height to dbh; characterizes stem taper and serves as an index of tree stability (Navratil 1995).

slash

The residue left on the ground after felling and tending and/or accumulating there as a result of storm, fire, girdling, or treatment with herbicide. It includes unutilized logs, uprooted stumps, broken or uprooted stems and the heavier branchwood (heavy slash), lighter tops and branchwood, twigs, leaves, bark, and chips (light slash) (NRC 1995).

snag

A standing dead tree from which the leaves and most of the branches have fallen (NRC 1995).

soil organic matter

All of the carbon-containing substances in the soil, except carbonates; a mixture of plant and animal residues in various stages of decomposition, the bodies of living and dead microorganisms, and substances synthesized from breakdown products of the above (Fisher and Binkley 2000).

soil parent material

The unconsolidated inorganic material from which mineral soil is formed by action of physical, chemical, and biological processes acting over time (Kimmins 1997).

soil profile

A vertical section of soil that extends through all its horizons (Hayden *et al.* 1995).

soil texture

The relative proportions of soil particles like sand, silt, and clay (Hayden *et al.* 1995).

soil type

A designation for soil classification that is used in FEC systems in Ontario. Soil types are groups of forest soil profiles based on specific ranges of texture, depth, moisture regime, calcareousness, and forest humus form. They occur at the ecoelement level of the ELC hierarchy and at spatial scales ranging from 1:1,000 to 1:20,000 (Taylor *et al.* 2000).

spacing

noun

The distance between trees in a plantation, a thinned stand, or a natural stand (NRC 1995).

verb

see juvenile spacing

species composition

The makeup of species occupying a given site, based on percentage of total basal area (Hayden *et al.* 1995).

species diversity

The variety of different biological species present in an ecosystem. Generally, high diversity is marked by many species with few individuals in each (Brady and Weil 1999).

species richness

The number of different species present in an ecosystem, without regard for the distribution of individuals among those species (Brady and Weil 1999).

spot application

Applying pesticides and/or fertilizers onto patches (NRC 1995).

stand (synonym: forest stand)

A community of trees possessing sufficient uniformity in composition, constitution, age, arrangement, or condition to be distinguishable from adjacent communities (OMNR 1996).

standard

A tree selected to remain standing, after the rest of the stand has been felled over a younger or a new crop, for some special purpose, e.g. shelter, seeding, production of a special quality, or size of timber (NRC 1995).

stand composition

see composition

stand composition type

A category of stand classification used to describe tree species composition for boreal mixedwood management.

stand condition

1. Specifically, in this guide, refers to the combination of stand composition type and stage of stand development.
2. In a general sense, refers to various characteristics and attributes associated with a stand (e.g. health, vigour, density, etc.).

stand development

1. The growth of a stand through its various developmental stages—from seedling or coppice through thicket, sapling, and pole to the tree stage, i.e. to maturity, and finally, to overmaturity (NRC 1995).
2. The part of stand dynamics concerned with changes in stand structure over time (Oliver and Larson 1996).

stand dynamics

see forest stand dynamics

stand establishment

see establishment

stand initiation stage

Colonization of the available free-growing space by trees following a stand-replacing disturbance (e.g. fire). In the boreal forest, trees that initially dominate the site are typically pioneer species such as aspen and birch, although this is not always the case (Chen and Popadiouk 2002).

stem exclusion stage

The stage of stand development immediately following the stand initiation stage. All available growing space in the canopy is fully occupied by trees. Inter- and intra-species competition occurs as individual trees expand in size. Vertical canopy stratification often takes place at a later phase of this stage (Chen and Popadiouk 2002).

stem injection (tree injection)

The deliberate introduction, by pressure or simple absorption, of a chemical—generally a water-soluble salt in solution—into the sapstream of a living tree (NRC 1995).

stocking

An expression of the adequacy of tree cover on an area, in terms of crown closure, percentage of stocked quadrats, number of trees, basal area, or volume, in relation to a pre-established managerial norm (OMNR 1996).

fully stocked

Productive forest land stocked with trees of merchantable species. These trees by number and distribution or by average dbh, basal area, or volume are such that at rotation age they will produce a timber stand that occupies the potentially productive ground. They will provide a merchantable timber yield according to the potential of the land. The stocking, number of trees, and distribution required to achieve this will be determined from regional or local yield tables or by some other appropriate method (NRC 1995).

partially stocked

Productive forest land stocked with trees of merchantable species insufficient to utilize the complete potential of the land for growth such that they will not occupy the whole site by rotation age without additional stocking. Explicit definition in stems per hectare, crown closure, relative basal area, etc., is locally or regionally defined and is site-specific (NRC 1995).

satisfactorily stocked

Productive forest land that has been regenerated naturally or artificially to at least a minimum number of well-established, healthy trees of merchantable species that are free from noncrop competition and sufficient to produce a merchantable timber yield at rotation age (NRC 1995).

strip cutting

Removal of the crop in strips in more than one operation, generally for encouraging natural regeneration or protecting fragile sites. A spatial variation of the conventional clearcut harvest method (NRC 1995).

structure

The distribution of trees in a stand or group by age, size, or crown classes (e.g. all-aged, uneven-aged, regular, and irregular structures (NRC 1995).

structural diversity

One of the measures of biological diversity in forest ecosystems. It refers to the variation in tree size and canopy layering, the variety of different life forms of vegetation (trees, herbs, shrubs, mosses, climbers, epiphytes, etc.), and the relative size and abundance of standing dead trees (snags) and decaying logs on the ground (coarse woody debris). Structural diversity refers to these features within ecosystems across the local landscape (beta structural diversity) (Kimmins 1997).

stump treatment

Application of herbicides to, or near, hardwood stumps to prevent coppicing. Also, fungicides or paint can be applied to prevent fungal infection (NRC 1995).

subcanopy

Stand stratum consisting of trees of intermediate, overtopped/suppressed, open understorey, and understorey crown classes (Popadiouk *et al.*, in prep.).

succession

Changes in species composition in an ecosystem over time, often in a predictable order (OMNR 1996).

supplemental regeneration

The establishment of target or acceptable trees in areas of inadequate stocking to achieve the prescribed minimum density, stocking, or distribution of stems, either in plantations or areas of natural regeneration.

suppressed tree (synonym: overtopped)

Trees with crowns entirely below the general level of the canopy of even-aged groups of trees, receiving no direct light either from above or the sides (NRC 1995).

suppression

The process whereby certain trees, shrubs, etc., in a community become weakened, essentially through the competition of neighbours but also by extension, through human intervention and selective browsing by livestock (NRC 1995).

surface fire

Fires with generally low intensity and severity and rapid rate of spread that burn litter and dead herbs and shrubs. Surface fires generally do little damage to live trees and soil where they occur frequently and there has been little accumulation of fuels (Kimmins 1997).

tending

Any operation that is carried out to improve the survival, growth or quality of a young to mid-rotation forest stand, including cleaning, thinning, liberation or compositional treatment, pruning, or fertilization (adapted OMNR 1996).

thinning

A cutting made in an immature crop or stand primarily to accelerate diameter increment but also, by suitable selection, to improve the average form of the trees that remain. The removal of trees may be from the dominant and codominant crown classes to favour the best trees of those same crown classes (known as crown thinning), or the removal of trees may be to control stand spacing and favour desired trees using a combination of thinning criteria without regard to crown position (known as free thinning) (OMNR 1996).

commercial thinning

The partial removal of overstorey trees in well-stocked stands where some portion of the trees have reached a merchantable size and where the sale of the timber will potentially earn a positive financial return (adapted OMNR 1996). The primary objective is to enhance the growth response (and perhaps form and quality) of the remaining stems while maintaining the original overstorey species composition.

low thinning

The removal of trees from the lower crown classes to favour those in the upper crown classes (NRC 1995).

high (crown) thinning

The removal of trees from the dominant and codominant crown classes to favour the best trees of those same crown classes (NRC 1995).

mechanical thinning

Thinning involving mechanical removal of trees in rows or strips, or by using fixed spacing intervals (NRC 1995).

pre-commercial thinning

A thinning at the stem exclusive stage that does not yield trees of commercial value, and is usually designed to improve crop spacing without altering the species composition of the future stand. In Ontario, the term pre-commercial thinning is generally used in relation to even-aged management only. Pre-commercial thinning in uneven-aged management is referred to as "improvement cutting" or stand improvement (after OMNR 1996).

trampling

A form of manual site preparation or tending where stems are trampled to suppress non-crop (particularly mountain maple) competition.

tree-length logging

The removal of only the merchantable length of the tree to the roadside. Limbing and topping occurs at the stump (OMNR 1997c).

tree improvement

The control of parentage combined with other silvicultural activities (such as site preparation) to improve the overall yield and quality of products from forest lands (OMNR 1996).

tree marking

Selection and indication, usually by marking with paint on the stem, of trees to be felled or retained (NRC 1995).

two-stage harvesting

A clearcutting harvest method where harvesting occurs in two distinct stages (Navratil *et al.* 1994). The (typically intolerant hardwood) overstorey is carefully harvested in the first pass with protection of the (typically conifer) understorey. The second pass harvests the released understorey decades later when it matures.

understorey crown class

see crown class; understorey

underplanting

Planting young trees under the canopy of an existing stand (NRC 1995) before final harvest.

undesirable species

Species that conflict with, or do not contribute to, the management objectives (NRC 1995).

uneven-aged stand

A forest or stand that contains at least three age classes intermingled intimately on the same area (Smith *et al.* 1997).

uneven-aged management

Silvicultural systems in which stands have an uneven-aged structure (e.g. selection systems) (after OMNR 1996).

unmerchantable

A tree or stand that has not attained sufficient size, quality, and/or volume to make it suitable for harvesting (NRC 1995).

vegetation management

Management of the interactions between crop and noncrop vegetation to manipulate succession (Kimmins 1997).

V-type

see vegetation type

vegetation type

A designation for vegetation classification that is used in FEC systems in Ontario. Vegetation types are mature forest plant communities based on specific ranges of plant species composition and abundance. They occur at the ecoelement level of the ELC hierarchy and at spatial scales ranging from 1:1,000 to 1:20,000 (Taylor *et al.* 2000).

vegetative reproduction (propagation)

Reproduction by a root, leaf, or some other primary vegetative part of a plant (OMNR 1997c). Includes root suckering and stump sprouts.

veteran

A tree that has escaped logging, windthrow, or fire, and occupies a dominant position in the stand (NRC 1995).

windbreak

A small-scale shelterbelt or other barrier, natural or artificial, maintained against the wind (NRC 1995).

windfall

1. A tree or trees thrown down or with their stems broken off or other parts blown down by the wind.
2. Any area on which the trees have been thrown down or broken by the wind (NRC 1995).

windfirm

Of trees, able to withstand strong winds, i.e. to resist windthrow, windrocking, and major breakage. Such trees may not remain upright but show wind lean, or wind bend, or both (NRC 1995).

whip

Any slender tree that the wind causes to lacerate the crowns of its neighbours (NRC 1995).

windrow

Slash, brushwood, etc., concentrated along a line so as to clear the intervening ground between two of them (NRC 1995).

windthrow

1. Uprooting by the wind.
2. Tree or trees so uprooted (NRC 1995).

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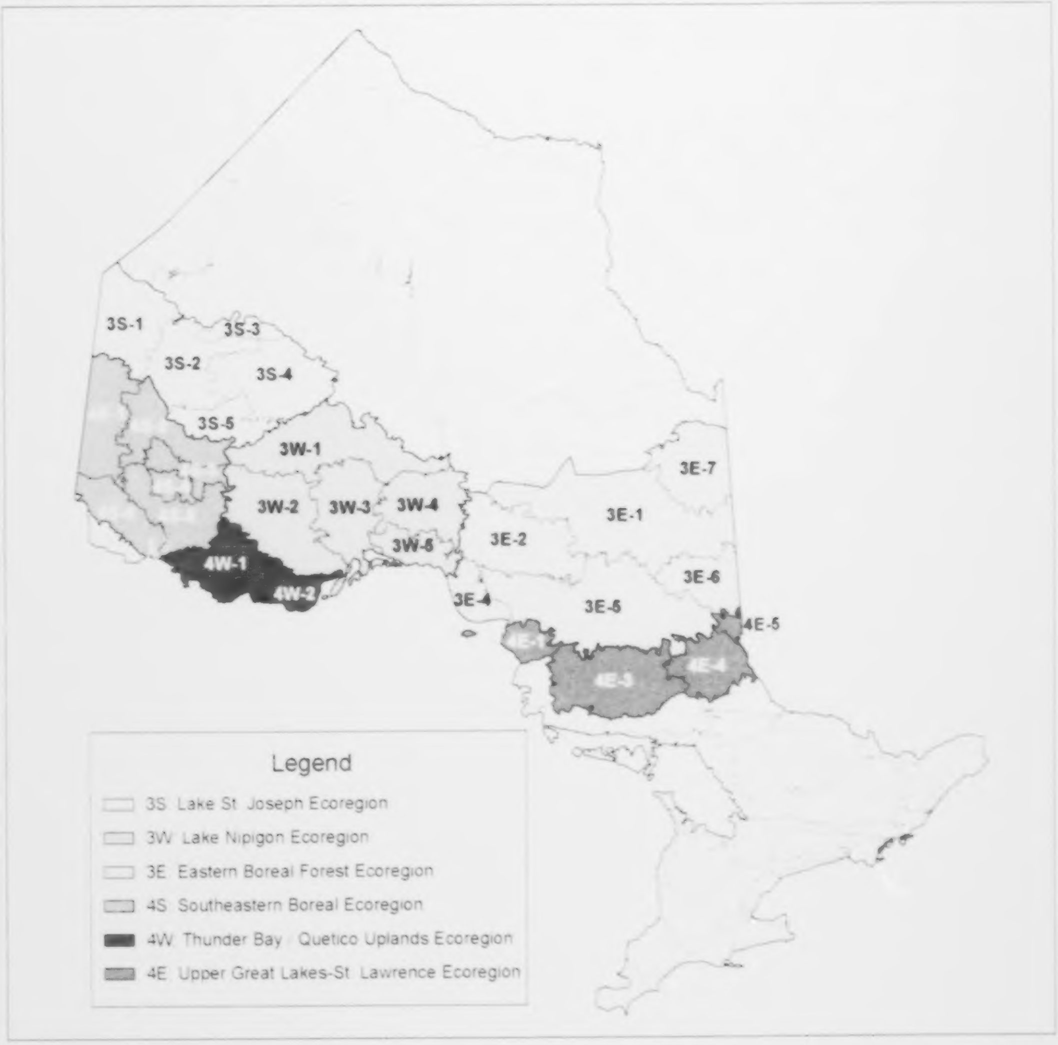
APPENDIX 1: ECOZONES AND ECOREGIONS OF THE APPLICATION AREA

The area of application for this guide lies completely within the Ontario Shield ecozone (though does not include the entire zone). The Ontario Shield ecozone contains nine ecoregions, six of which are within the application area of the guide (3S, 3W, 3E, 4S, 4W, and 4E). All six share common precambrian bedrock geology.

Ecoregions are differentiated by their broad regional climatic regimes which influence vegetation distribution and productivity (Crins and Gray, in prep.). The re-delineation of the ecoregions is a refinement of the work done by Angus Hills between 1944 and 1975. Hills' ecoregions were determined by drawing lines around areas in which the pattern of vegetation succession for the modal site (site representative of the climate and geological history, e.g. with normal moisture regime) was the same. In all of the ecoregions covered by this guide, the modal site succession is a mixedwood succession. The vegetation pathway is different for the modal site in different ecoregions (Hills 1959). Hills believed that these different successional pathways were a direct result of the different climates and geologic histories of the ecoregions. Differences between ecoregions may, in some cases, be sufficient to require different silvicultural treatments.

The climate, topography, soils, forest cover, and disturbance regime for each ecoregion are discussed in the following pages and some comparisons between ecoregions are made.

Figure 1. Ecozones and ecoregions of the application area.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3E-7
3E-1
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4E-1
4E-3
4E-4
Legend
3S Lake St. Joseph Ecoregion
3W Lake Nipigon Ecoregion
3E Eastern Boreal Forest Ecoregion
4S Southeastern Boreal Ecoregion
4W Thunder Bay - Quetico Uplands Ecoregion
4E Upper Great Lakes-St. Lawrence Ecoregion

Ecoregion 3S

(Lake St. Joseph Ecoregion)

Climate

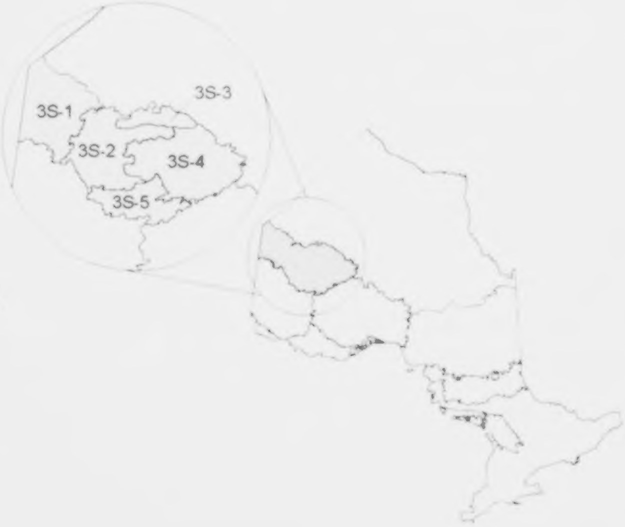
The climate in this area is moderate microthermal, moist sub-humid, southern boreal (Hills 1976), receiving less than 725 millimetres of precipitation annually (Crins and Gray, in prep.). This ecoregion is drier than 3W which lies to its east, but still relatively cool in temperature. The humidity in this ecoregion (and the others with the S label) is influenced by the continental dry air mass that passes over the prairies of both the United States and Canada. This air mass does not contain much water relative to the air masses that have passed over the Great Lakes. Its cooler temperature relative to 4S is a function of its more northerly latitude.

Topography

This ecoregion has irregular relief, particularly in the areas where glaciation was intense and resulted in rocky parallel ridges separated by either lakes or poorly drained depressions (Rowe 1972). Areas of exposed bedrock are common in the westernmost portion of the region. Elevation gradually increases from west to east (Baldwin *et al.* 2000).

Soils

The dry cool temperatures of this ecoregion favour the formation of forest humus forms such as mors. Fibrimors are very common here since cooler temperatures mean very slow decomposition. The slightly wetter conditions in 3W and 3E usually generate humifibrimors and some humimors. On peaty soils, decomposition is usually slow, causing a dominance of fibricpeatymors on organic soils. Almost all of this ecoregion was covered by the waters of glacial Lake Agassiz during the last glaciation (Teller 1984). This lake laid down clay deposits which are seen today as luvisolic soils on well-drained sites. Despite inundation by Agassiz waters, much of the area is bedrock controlled, particularly in the westernmost portion of the ecoregion, where soils are often very shallow. There are some areas of barren rock where the precambrian bedrock is exposed. Podzolic soils often form on the coarse, well-drained portions of the landscape such as the deeper drift found on slopes. Only a small portion of the area has organic soils which are often found in poorly drained depressions.



Forest Cover

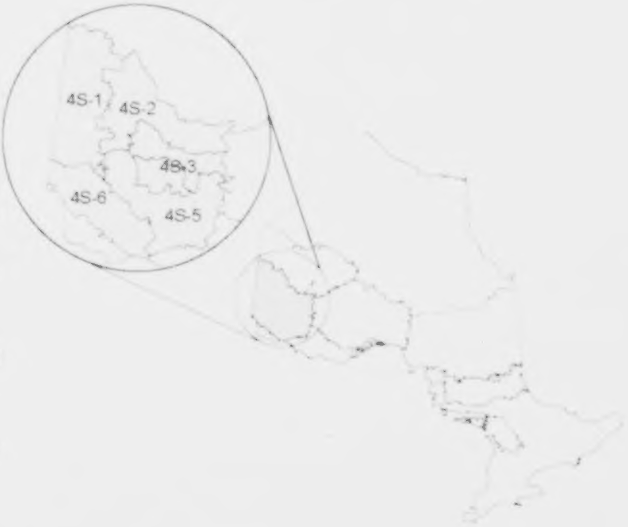
The vegetation in this ecoregion is boreal in nature. The modal site for this ecoregion has a mixedwood succession of jack pine or trembling aspen in early successional stages and black or white spruce or balsam fir in the late successional stages (Hills 1966). Black spruce is the dominant tree species, occurring in uplands in combination with jack pine and in lowlands in combination with larch (Rowe 1972). White birch is a common component in stands, particularly in a post fire situation. Mixedwoods of black spruce, white spruce, balsam fir, trembling aspen, and white birch are found on south-facing slopes with favourable soil conditions. The drier forest conditions here mean an increase in the frequency of occurrence of rock cranberry (*Vaccinium vitis-idaea*) and common bearberry (*Arctostaphylos uva-ursi*) (Sims *et al.* 1997).

Disturbance Regime

Fire is the dominant disturbance type in this ecoregion. The fire cycle found here of 100 to 300 years (Bridge 2001) is one of the shortest found in Ontario. The dry continental air mass that creates the dry climate in this ecoregion is likely at least partly responsible for the short fire return interval. The area of bedrock-controlled terrain at the westernmost boundary of the ecoregion has an even shorter return interval, ranging from 100 to 200 years (Bridge 2001). Spruce budworm and forest tent caterpillar have had repeated severe infestations over the last century. Unlike 3W to the east, moderate to severe infestations of jack pine budworm have also occurred in the last hundred years.

Ecoregion 4S

(Southestern Boreal Ecoregion)



Climate

The climate of this ecoregion is warm microthermal, moist sub-humid, hemi-boreal (Hills 1976). The region is dry as a result of the dry continental air mass but slightly warmer than ecoregion 3S due to its more southerly latitude. It is also warmer than ecoregion 3W, which is at approximately the same latitude, since 3W is greatly influenced by the cooling effect of Lake Superior which lies against its southern boundary. Ecoregion 4S, since it is not influenced by a large water body, is quite continental in climate. Ecoregion 4S is somewhat warmer in temperature than ecoregion 4W as the highlands west of Thunder Bay create an area of lower temperatures and fewer growing degree days.

Topography

The landscape in this ecoregion is moderately broken and thus has about equal portions of land with normal, warmer-than-normal, and colder-than-normal sites. Overall, this ecoregion has much less rugged topography than neighbouring 4W.

Soils

Most of the northern portion of this ecoregion is dominated by mor and moder with the occasional mull forest humus form. The southern part of the region has a larger portion of moder humus forms due to the warmer climate and resultant increase in soil fauna to mix the layers. Organic soils tend to be dominated by fibric and mesic peatymors in this region (Sims *et al.* 1997).

Like most of northwestern Ontario, this ecoregion was covered by glacial Lake Agassiz at the end of the last glaciation. This is still evident in the luvisols found in the lacustrine deposits in the Dryden area. The extreme western portion of the region near the Manitoba border has bedrock-controlled terrain. Podzolic soils are common in the remainder of the ecoregion on coarse-textured soils.

Forest Cover

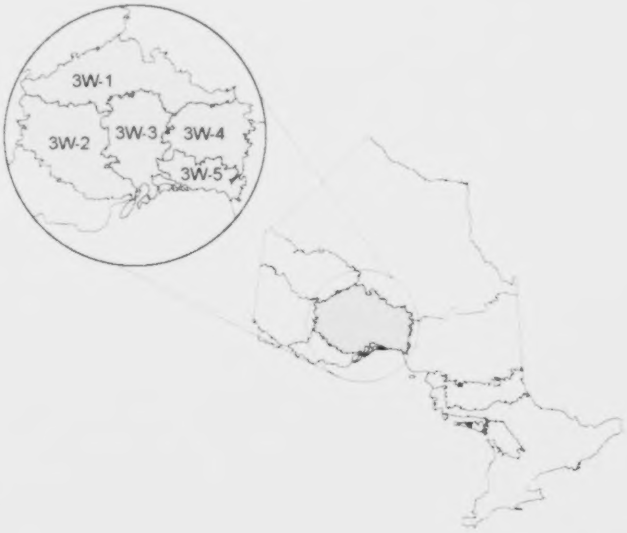
The forest in this ecoregion is predominantly boreal but has elements of the Great Lakes–St. Lawrence forest on sites with warmer than normal microclimate. The modal site for this ecoregion has a mixedwood succession starting with jack pine, trembling aspen, or white birch and succeeding to white or black spruce, balsam fir, or white pine (Hills 1966). Jack pine is common on sandy poor sites but also on clay soils after fire. Organic sites are dominated by black spruce and larch. White pine, which is considered a Great Lakes–St. Lawrence forest species, can be found on rocky areas, river banks, lake shores, and sandy ridges and in mixed forest on well-drained sites. Green ash (*Fraxinus pennsylvanica*), bur oak (*Quercus macrocarpa*), and white elm can be found in floodplain areas and are also considered to be Great Lakes-St. Lawrence species (Rowe 1972).

Disturbance Regime

The disturbance regime in ecoregion 4S is dominated by fire and has a relatively short fire cycle of 100 to 300 years (Bridge 2001). This cycle is very similar to the fire cycles in 5S and 3S, which are influenced by the same dry continental air mass from the prairies. Insects are also a major disturbance factor in this ecoregion as it has experienced major infestations of spruce budworm, forest tent caterpillar, and jack pine budworm during the last century.

Ecoregion 3W

(Lake Nipigon Ecoregion)



Climate

The climate here is moderate microthermal, dry-humid, southern boreal (Hills 1976). Temperatures are cool due to the moderating effect of Lake Superior but drier than to the east of Superior where the water picked up by the winds crossing the lakes is deposited. This area is cooler and wetter than the other western ecoregions, but comparatively drier than 3E. Ecoregion 3W receives 725 millimetres of precipitation compared to the 900 millimetres received in 3E.

Topography

The topography of this ecoregion is very variable, ranging from rugged-bedrock upland in 3W-5, to a smooth to gently rolling plain of bedrock in 3W-4. Areas of poorly drained flats of granitic sand are found in 3W-2. The Lake Nipigon area is a basin which is surrounded on three sides by plateaus of higher land and to the south by Lake Superior. The plateaus surrounding the Lake Nipigon basin are relatively level with a gentle slope towards the northeast.

Soils

The spillway for glacial Lake Agassiz ran across the top of Lake Nipigon and down its western side, leaving large areas of clay deposits. Luvisolic soils have developed on well-drained portions of this area. Podzols are the dominant soil order throughout the region outside of the Lake Nipigon area, particularly in the extensive sand and gravel deposits of the plateau around the Nipigon basin. Gleysols develop on moist mineral substrates while organic soils are found on sites with extremely poor drainage.

Forest Cover

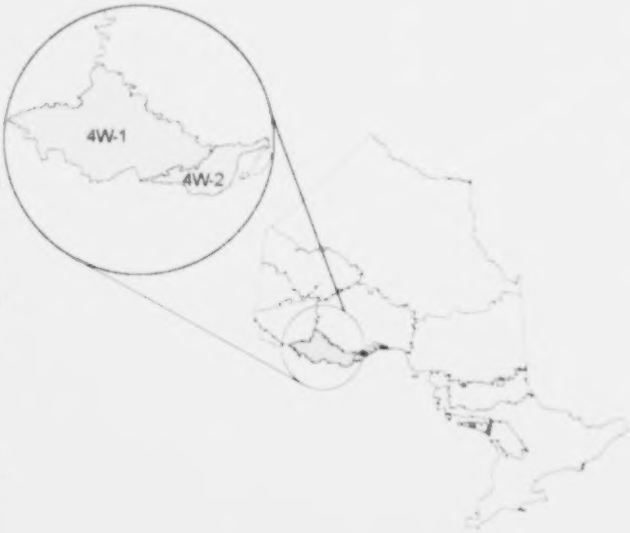
The plateau lands around the Nipigon basin, with their extensive sand deposits, support extensive areas of jack pine. Black spruce stands are found both in upland and lowland sites. The modal site position in this ecoregion starts succession with jack pine, trembling aspen, or white birch and succeeds to black spruce, white spruce, or balsam fir (Hills 1966). This is very similar to the classic successional pathway on boreal mixedwood sites. These sites develop a strong shrub understorey. In the Nipigon basin, black spruce dominates most communities from low-lying areas up most slopes. Upper or top slope positions are often jack pine stands. On the islands in Lake Nipigon, red and white pine stands are found on well-drained sites. (Rowe 1972).

Disturbance Regime

The average fire return interval for ecoregion 3W is 300 to 500 years (Bridge 2001), which is considerably shorter than that found in neighbouring ecoregion 3E. There are significant differences in fire cycle within the ecoregion as the basin around Lake Nipigon has a fire cycle of 600 to 1,500 years (Bridge 2001); this is quite similar to that found in the claybelt of 3E. This may be due to the maritime effect of both Lake Nipigon and Lake Superior. Insect damage has also been a major factor in this ecoregion. Major infestations of both spruce budworm and forest tent caterpillar have occurred over the last century.

Ecoregion 4W

(Thunder Bay/Quetico Uplands Ecoregion)



Climate

The climate of this ecoregion is warm to hottest microthermal, dry-humid, hemi-boreal to hardwood (Hills 1976). Temperatures are cooler in this ecoregion than in adjacent 4S and parts of 3W due to the influence of the highland area west of Thunder Bay that creates a pocket of cooler temperatures and fewer growing degree days for this ecoregion.

Topography

Round ridges of granitic bedrock and flat-topped ridges with intervening valleys are common in the highland area just west of Thunder Bay. To the west, towards Quetico, are areas of moderately rolling bedrock which can be bare or shallowly covered with soil (Hills 1959).

Soils

Warmer temperatures in this ecoregion favour the formation of moder and mor forest humus forms. Most of the ecoregion has podzolic soils forming on coarse-textured substrates. This is particularly true at the northern point of the ecoregion where a large beach and aeolian deposit can be found. Luvisols have formed in the areas where Lake Agassiz deposits dominate, while exposed bedrock is found on the granitic ridges west of Thunder Bay. Gleysolic soils form in areas of poor drainage.

Forest Cover

The vegetation in this ecoregion is a mixture of boreal and Great Lakes–St. Lawrence types with many authors such as Rowe (1972) and Thompson (2000) considering large portions of it to be Great Lakes–St. Lawrence. Though the largest portion of the ecoregion (as it is presently delineated) has boreal forest cover, Great Lakes species spread into this area following the last glaciation and are certainly a large component of the more southerly parts of the region. The modal site position for this ecoregion has a mixedwood succession starting with jack or red pine, trembling aspen, or white birch and ending with white or black spruce, balsam fir, or white pine (Hills 1966). Pure jack pine communities are common on coarse substrates but they often have white and red pine mixed in with them. White cedar is often found along shorelines and in rich treed wetlands, while black spruce and larch are frequent in more nutrient-poor peatlands (Rowe 1972). Species such as large tooth aspen, red maple, yellow birch (*Betula alleghaniensis*), basswood (*Tilia americana*), white elm, and red ash (*Fraxinus pennsylvanica*) can be found with some frequency in the more southerly portion of this ecoregion (Sims *et al.* 1997).

Disturbance Regime

Fire is the dominant disturbance force on the landscape in this ecoregion. The fire cycle for this ecoregion varies from 300 to 500 years (Bridge 2001) and is very similar to the cycles found in 4E and 3W. It is somewhat longer than the cycle seen in 4S, as this area is less influenced by the continental air mass from the western prairies and is more influenced by Lake Superior and the upland area just west of Thunder Bay. Insect defoliation has also had a large impact on this ecoregion as there have been severe infestations of spruce budworm, forest tent caterpillar, and jack pine budworm during the last century.

Ecoregion 3E

(Eastern Boreal Forest Ecoregion)

Climate

The climate is moderate microthermal, moist humid, southern boreal (Hills 1976), with the area generally receiving more than 900 millimetres of precipitation annually (Crins and Gray, in prep.). The cold maritime climate of Hudson Bay and James Bay creates a damp and cool climate, resulting in this area having fewer growing degree days than other locations in Canada with similar latitudes (Baldwin *et al.* 2000).

Topography

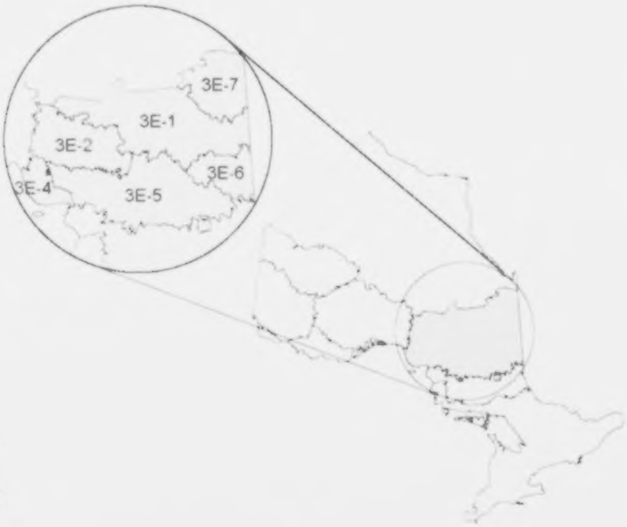
Topography in the claybelt portion (3E-1) of the ecoregion is very gentle as most of the landforms created by the retreat of the glacier have been buried by the clay deposited by glacial Lake Barlow–Ojibway. The site districts that make up the remainder of the ecoregion have rougher terrain (ground moraine and tills) and much lower proportion of organic soils.

Soils

Soils in 3E are relatively young and are dominated by mor, and occasionally moder, forest humus forms. The claybelt, formed by the glacial waters of Lake Barlow–Ojibway, is a prominent feature of the ecoregion with large areas of calcareous, lacustrine clays. Organic soils make up about 50 percent of the soils in the claybelt portion of the ecoregion (Ketcheson and Jeglum 1972). In the claybelt, luvisols are common due to the abundance of clay-size particles. The A horizons may be feric or humic and there is often an Ae horizon where eluviation of clay particles has taken place. This often corresponds with a Bt horizon where the clay particles have come to rest. Gleysols occur in situations where there is a high watertable and mottles and gley have formed. Due to the cooler climate, most of the peat is fibric though mesic and humic peats do occur. In the rest of the region, where clay particles are not as prevalent, podzols which have B horizons of humified organic matter with aluminium and iron are common on coarse to medium soils, particularly if they have conifer or heath vegetation.

Forest Cover

The forest of this ecoregion is typically boreal in nature. The succession on the modal site within this ecoregion follows the classical mixedwood successional pathway. According to Hills (1966) succession follows a pattern of trembling aspen, white birch, or balsam poplar as the pioneer species succeeding into a white spruce, black spruce, or balsam fir forest. However, balsam fir has not formed a large canopy component in recent years due, presumably, to the massive spruce budworm infestation that took place in this ecoregion from 1968 to 1995 (Fleming *et al.* 2000). Black spruce and larch are typically found in the organic deposits. Red and white pine, as well as sugar maple, red maple, and yellow birch are found on sites with warmer than normal microclimates. White cedar is found in flood plains and in areas with teluric water while white elm, balsam poplar, and black ash can be found on the flood plain.

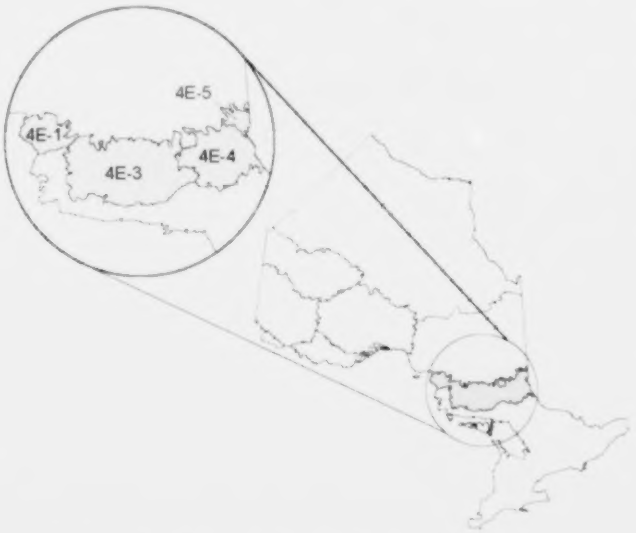


Disturbance Regime

The dominant disturbance agent in this ecoregion is fire, but the fire cycle (500 to 1,200 years) is the longest of all areas covered by this guide (Bridge 2001) due to the more humid climate caused by the influence of Hudson and James bays. The fire cycle for the claybelt itself is even longer at 600 to 1,500 years (Bridge 2001). The clay deposits from glacial Lake Barlow–Ojibway have facilitated the development of peat deposits which are less prone to fire than drier substrates which also increase the length of the fire cycle. Insect damage from spruce budworm and forest tent caterpillar, along with windthrow damage, also contribute greatly to the overall disturbance regime.

Ecoregion 4E

(Upper Great Lakes–St. Lawrence Ecoregion)



Climate

The climate is considered warm microthermal, moist humid, hemi-boreal (Hills 1976). The areas east of Lake Superior experience wetter conditions because air masses moving across the lake pick up water which is then deposited at the east end of Lake Superior.

Topography

The topography of this ecoregion is much more broken than Ecoregion 3E as there are deeply faulted valleys in the area bordering Lake Superior, numerous north-south flowing river systems in which valley train deposits are found, and localized areas of end moraines, aeolian deposits, lacustrine deposits, and eskers exist. Though some of these features are found to the north in 3E, many of them have been buried by deposits from Lake Barlow–Ojibway. Here, the deposits remain uncovered. The exception to this is found in the Little Claybelt of Ecodistrict 4E-5 where there is an undulating clay plain.

Soils

Soils in this ecoregion are slightly older than those found in 3E as the area has been deglaciated longer. The longer period of time since glaciation combined with the slightly warmer temperatures mean that forest humus forms such as moders and occasionally mulls are more common. Warmer temperatures also favour the soil organisms that mix the organic matter with the mineral soils, making Ah layers generally deeper than those found in 3E. The soils of the Little Claybelt area of 4E are often luvisols due to the abundance of clay-sized particles which allows for the formation of a Bt horizon. Podzolic soils are abundant in the rest of this ecoregion (no Bt horizon) and have horizons with aluminium and iron deposits along with humified organic material. These soils are common on coarse soil textures. Brunisols are also found. In areas where there are high water tables (moist mineral soils), gleysols develop throughout the ecoregion.

Forest Cover

The descriptions of the forest cover in this ecoregion vary greatly depending on the author (Taylor *et al.* 2000, Chambers *et al.* 1996). Rowe (1972) and Thompson (2000) describe the area as being boreal forest, while Crins and Gray (Crins and Gray, in prep.) considers the ecoregion to be Great Lakes–St. Lawrence forest. The source of some of the disagreement may be that this ecoregion contains what Thompson (2000) describes as the transition zone between the boreal and Great Lakes–St. Lawrence forests. Thompson describes the transition zone as being at the 5° C mean annual isotherm east of Lake Superior; or at the line depicting 120 frost free days (Pastor and Mladenoff 1992). Only a few very hardy Great Lakes–St. Lawrence species, particularly red and white pine occur at the northern edge of the ecoregion. The number of Great Lakes–St. Lawrence species increases greatly towards the south. The fire cycle for ecoregion 4E is 300 to 500 years, which is the same as that found in the boreal ecoregions 2W, 3W, and 4W but considerably shorter than that found in ecoregion 3E. Whether boreal or not, the forest cover on the modal site position is trembling aspen, white birch, or balsam poplar at the beginning of succession and white spruce, balsam fir, and red or white pine in late succession (Hills 1966). Red and white pine also occur on rocky outcrops and jack pine on sandy soils, particularly after fire. Jack pine-black spruce associations are typically found in the northern part of the ecoregion (Chambers *et al.* 1996). Valleys and other protected areas often have cover made up of sugar maple, red maple, and yellow birch.

Disturbance Regime

The dominant disturbance agent in this ecoregion is fire with a fire cycle of 300 to 500 years (Bridge 2001). This is considerably shorter than the cycle found in 3E. Areas of extensive defoliation by forest tent caterpillar and spruce budworm also occur in this ecoregion and often at about the same time as they occur in ecoregion 3E (Fleming *et al.* 2000).

Summary table of the ecozones and ecoregions of the application area.

Ecoregion	**Bedrock**	**Climate**	**Topography**	**Dominate Soil Characteristics**	**Modal Forest Cover**	**Disturbance Regime**
3E	• Precambrian, Archean Era	• Moderate microthermal, moist humid, southern boreal	• Ecodistrict 3E1 gently rolling, remainder rougher	• Mors, Luvisols and Peaty Mors in Claybelt • Podzols common off claybelt	• Pioneers: Pt, Bw, Pb • Late Succession: Sb, Sw, Bf	• Fire Cycle: 500–1200 years • spruce budworm, forest tent caterpillar
4E	• Precambrian with Proterozoic and Archean Eras	• Warm microthermal, moist humid, hemi-boreal	• Moderately rolling	• Moders, Luvisols in Little Claybelt • Podzols abundant	• Pioneer: Pt, Bw, Pb • Late Succession: Sw, Bf, Pr, Pw	• Fire Cycle: 300–500 years • spruce budworm and forest tent caterpillar
3W	• Precambrian, Archean Era • Proterozoic Era around Nipigon	• Moderate microthermal, dry-humid, southern boreal in the north • Warm microthermal, dry-humid, hemi-boreal in the south	• Strongly broken around Nipigon and weakly broken in the remainder	• Luvisols in Nipigon area • Podzols throughout	• Pioneer: Pj, Pt, Bw • Late Succession: Sb, Sw, Bf	• Fire Cycle: 300–500 years • spruce budworm and forest tent caterpillar
4W	• Precambrian, Archean and Proterozoic from Southern Province.	• Warm to hottest microthermal, dry humid, hemi-boreal and hardwood	• Round granitic ridges near Thunder Bay and moderately rolling bedrock in the remainder	• Moder and Mor forest humus forms • Mostly Podzolic soils	• Pioneer: Pj, Pr, Pt, Bw • Late Succession: Sw, Sb, Bf ,Pw	• Fire Cycle: 300–500 years • spruce budworm, forest tent caterpillar, and jack pine budworm
3S	• Precambrian, Archean Era	• Moderate microthermal, moist subhumid, southern boreal	• Irregular relief with large areas of exposed bedrock in western portion.	• Mor forest humus forms • Podzols	• Pioneer: Pj, Pt • Late Succession: Sb, Bf, Sw	• Fire Cycle: 100–300 years • spruce budworm, forest tent caterpillar and jack pine budworm
4S	• Precambrian, Archean Era	• Warm microthermal, moist subhumid, hemi-boreal	• Moderately broken	• Mor humus forms • Luvisols near Dryden • Podzols throughout	• Pioneer: Pj, Pt, Bw • Late Succession: Sw, Sb, Bf, Pw	• Fire Cycle: 100–300 years • spruce budworm, forest tent caterpillar, jack pine budworm

APPENDIX 2: CREATING BOREAL MIXEDWOOD FOREST UNITS AND PREPARING FOREST OPERATIONS PRESCRIPTIONS

Figure 1. A flowchart showing how to apply this guide when developing forest units, silvicultural ground rules, and treatment packages.

Step 1. Develop preliminary current and future boreal mixedwood forest unit definitions and sort criteria.

- Review:
  - boreal mixedwood ecosite and broad soil group relationships (Section II – Table 2)
  - relationships among broad soil groups, generalized boreal mixedwood forest composition types, ecosites, soil S-types, and vegetation V-types (Section II – Tables 3 and 4)
  - stand development stages (Section II)
  - sort criteria for the generalized boreal mixedwood forest composition types
- Consider:
  - the sort criteria for the boreal mixedwood forest composition types
  - stand development patterns (both natural and in response to silvicultural interventions) of the related ecosites and ecoelements
  - potential site and forest productivity of the related ecosites and ecoelements
  - potential differences in operability and merchantability of the related ecosites and ecoelements
  - potential differences in product availability, yield, and economics of the related ecosites and ecoelements
  - the ability to develop a concise suite of related silvicultural ground rules and treatment packages
  - the relationship of proposed boreal mixedwood forest units to the regional standard forest units

Step 2a. Query the forest resource inventory (FRI) stand list/database using preliminary boreal mixedwood forest unit definitions and generate a list of stands classified by forest unit.

Step 2b. Assess variability in stand composition, age, stocking, and ecosites for each forest unit. Based on this assessment, confirm final forest units and classify landbase.

- Assess:
  - relationships between forest units and individual ecosites
  - age class distribution by ecosites; age class distribution by forest unit
  - stocking by age class for each forest unit-ecosite combination
  - individual species composition by age class for each forest unit–ecosite combination
- Determine the reason for the variation that has been identified:
  - inventory bias or inaccuracy
  - unique local ecology
  - management history
- Improved knowledge of the ecological variability of the boreal mixedwood forest units will:
  - result in refinements to the boreal mixedwood forest unit criteria and definitions
  - improve inputs for strategic forest management modeling (natural, post-fire, and silvicultural succession rules)
  - improve the documentation concerning forest unit development for future adaptive management activities
  - improve the development of silvicultural ground rules
- Note:
  - silvicultural ground rules must be developed for each forest unit–ecosite combination (FMPM–A49)

Return to Step 1 and refine boreal mixedwood unit definitions if necessary

Proceed to Step 3.

Step 3. Complete the descriptions of each of the (final) current and future forest units. Include a listing of the boreal mixedwood composition type(s), ecosite(s), and broad soil group(s) in each current and future forest unit.

Step 4. For each current forest unit-stand composition type combination (from step 3), list the future boreal mixedwood forest conditions (at canopy transition) that may be achieved through silviculture.

- Refer to Management Interpretation Tables and Fact Sheets in Section VI.

Step 5. List the eligible silviculture systems, methods and treatments that may be employed to achieve the future stand condition(s) identified in Step 4.

- Refer to Section V: Understanding the Management Interpretations.
- Worksheet 1 may be used; blank copy provided in Appendix 5.

Current Forest Unit

Future Forest Unit

Broad Soil Group

Current Stand Composition Type

Future Stand Composition Type

Stand Development Stage(s)

Pre-harvest Treatments	Silvicultural Systems	Harvest Methods	Logging Methods	Regeneration Treatments	Site Preparation Treatments	Tending/Cleaning Treatments	Tending/ Intermediate Stand Treatments

Step 6. Select the desired future stand condition(s) from Step 4.

Step 7. Define a regeneration standard for the desired boreal mixedwood future stand condition.

- Refer to Section V: Understanding the Management Interpretations.

Proceed to Step 8.

Step 8. From the worksheet completed in Step 5, develop suites of eligible silvicultural ground rules and treatment packages that would lead from each current stand condition to each selected future stand condition.

- A silvicultural ground rule consists of:
    - current stand condition (now)
    - future stand condition (then)
    - silvicultural treatment package (how you get from now to then)
- There may be more than one silvicultural treatment package for each silvicultural ground rule.
- Identify internal and external factors affecting the possible use or choice of silvicultural systems and silvicultural activities that, if implemented, can achieve the desired future stand condition (e.g. Forest Management Plan objectives).

  e.g. resources for silvicultural effectiveness monitoring and condition surveys; wood supply/product objectives; habitat values; forest health; landscape considerations; markets and utilization; values and areas of concern; economics; financial evaluation of activities; worker health and safety; access.
- Generate a list of all possible "harvest-to-harvest" strings of silvicultural activities by current stand condition and desired future stand condition that are theoretically possible, biologically effective, and could be implemented in the context of known internal and external factors.
- Worksheet 2 may be used; blank copy provided in Appendix 5.

Current Forest Unit **Future Forest Unit**

Broad Soil Group

Current Stand Composition Type **Future Stand Composition Type**

Stand Development Stage(s)

Pre-harvest Treatments	Silvicultural Systems	Harvest Methods	Logging Methods	Regeneration Treatments	Site Preparation Treatments	Tending/Cleaning Treatments	Tending/ Intermediate Stand Treatments

Step 9. Identify preferred silvicultural treatment package.

- Determine by considering the feasibility and reliability of silvicultural treatments, and an analysis of various economic, ecological, and social considerations.

Step 10. Document silvicultural ground rules for each unique combination of current stand condition and future stand condition at transition.

- Document the silvicultural ground rules/silvicultural treatment package combinations in Table FMP-10.

Example Using the Flowchart in Figure 1

This example uses references to Northwest Region ecosites.

STEP 1

Develop preliminary current and future boreal mixedwood forest unit definitions and sort criteria.

In this example:

Boreal mixedwood conditions were categorized into three general forest units, as follows:

- Hardwood Dominated Mixedwood
  80% ≥ Hardwood > 50%
- Spruce Dominated Mixedwood
  80% ≥ Spruce ≥ 40%, All Conifer > All Hardwood, and Bf < 20%
- Softwood Dominated Mixedwood
  Mixed Conifer (Sp*+ Bf) > Hardwood, and, Bf > 20%

Each of these general forest units may be subdivided into more specific forest units based on differences in productivity, operability, ecological variability, or other considerations outlined in Step 1 of the flowchart.

For demonstration purposes, the Hardwood Dominated Mixedwood forest unit was further subdivided into four forest units for the planning process (a, b, c, and d below). These subdivisions were based on productivity and ecological differences that were considered to be relevant to management interpretations and objectives.

For example, for the Hardwood Dominated Mixedwood (80% ≥ Hardwood > 50%) subdivisions may be:

- HrdDomMxd 1
  Pt > Bw
  a) HrdDomMxd 1a: coarse soils (ES16, ES19)
  b) HrdDom Mxd 1b: other boreal mixedwood soils (ES28, ES29, ES23, ES33)
- HrdDomMxd 2
  Bw > Pt
  c) HrdDomMxd 2a: coarse soils (ES16, ES19)
  d) HrdDomMxd 2b: other boreal mixedwood soils (ES28, ES29, ES23, ES33)

STEP 2A

Query the FRI stand list/database using preliminary boreal mixedwood forest unit definitions and generate a list of stands classified by forest unit.

Stand composition and ecosite typing would be the main elements of a simple sorting rule used to allocate FRI stands to one of the current forest units. Other criteria that are available from the FRI database, such as stocking and site class, may also be applied to sort the stands into each of the preliminary forest units.

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* Sp = Sw and/or Sb

In this example:

The simple sort rule was: FRI composition + ecosite → forest unit

Examples:

Stand 87	$Pt^6Sp^3Bf^1$	+ ES19	→	HrdDomMxd 1a
Stand 105	$Pt^6Sp^2Bw^1Bf^1$	+ ES28	→	HrdDomMxd 1b
Stand 121	$Bw^4Pt^2Sp^3Bf^1$	+ ES16	→	HrdDomMxd 2a
Stand 119	$Pt^5Bw^1Bf^3Sp^1$	+ ES29	→	HrdDomMxd 1b

STEP 2B

Assess variability in stand composition, age, stocking, and ecosites for each forest unit. Based on this assessment, confirm final forest units and classify landbase.

The preliminary forest units should be assessed to determine the degree of variability (within and between the forest units) of key characteristics that are relevant to the management objectives and interpretations. The results of this assessment may be used to modify the preliminary forest units created in Step 1.

In this example:

Age class distribution, average species composition, and stocking by age class were assessed for each of the preliminary forest units (other assessments may apply, depending on management objectives).

The results of the two assessments for the four HrdDomMxd forest units are outlined in Tables 1 and 2 below.

Table 1. Age class distribution by forest unit.

Forest Unit	Age Class Distribution (ha)						
	Barren and Scattered	0 – 20	20 – 40	40 – 60	60 – 80	80 – 100	100 +
HrdDomMxd 1a	4,050	25,700	12,300	32,250	31,600	13,400	11,700
HrdDomMxd 1b	3,160	28,400	27,500	43,000	31,800	21,300	18,400
HrdDomMxd 2a	2,670	12,700	24,300	23,200	14,800	9,100	1,200
HrdDomMxd 2b	500	2,600	4,700	1,300	3,800	2,200	1,450

Table 2. Average species composition and average stocking by forest unit and age class.

	Age Class Distribution (years)						
Forest Unit	**Barren and Scattered**	**0 – 20**	**20 – 40**	**40 – 60**	**60 – 80**	**80 – 100**	**100 +**
HrdDom Mxd 1a	Pt^7Bf^3 0.2	$Pt^6Bw^2Sp^2$ 0.8	$Pt^5SP^3Bw^2$ 0.7	$Pt^6Sp^2Bw^2$ 0.7	$Pt^6Bw^2Bf^2$ 0.6	$Pt^6Bf^3Bw^1$ 0.6	$Pt^6Sp^2Bf^2$ 0.5
HrdDom Mxd 1b	$Pt^6Bf^2Sp^1$ 0.3	$Pt^7Sp^2Bf^1$ 0.8	$Pt^7Sp^2Bw^1$ 0.8	$Pt^6Sp^2Bf^2$ 0.7	$Pt^7Bf^2Sp^1$ 0.8	$Pt^7Sp^2Bf^1$ 0.7	$Pt^6Sp^2Bf^2$ 0.6
HrdDom Mxd 2a	$Bw^5Bf^3Pt^2$ 0.2	$Bw^7Sp^2Pt^1$ 0.8	$Bw^6Pt^2Sp^2$ 0.6	$Bw^7Bf^2Pt^1$ 0.6	$Bw^7Sp^2Bf^1$ 0.6	$Bw^6Sp^2Bf^2$ 0.6	$Bw^6Bf^3Sp^1$ 0.5
HrdDom Mxd 2b	$Bw^4Pt^3Sp^3$ 0.3	$Bw^4Sp^3Pt^3$ 0.8	$Bw^5Pt^2Sp^3$ 0.7	$Bw^5Pt^2Sp^3$ 0.8	$Bw^4Pt^3Sp^3$ 0.8	$Bw^5Pt^2Bf^3$ 0.7	$Bw^4Pt^2Bf^4$ 0.7

In this example, differences in stand composition, stocking, and age class distribution were identified (Tables 1 and 2) and considered relevant to management interpretations and stand development information.

- There is a greater percentage of white birch (Bw) and a reduced percentage of balsam fir (Bf) in the HrdDomMxd 1a forest unit than in the HrdDomMxd 1b forest unit (this will influence silvicultural opportunities and yields).
- There is a greater percentage of trembling aspen (Pt) and higher overall stocking in the HrdDomMxd 2b forest unit than in HrdDomMxd 2a forest unit (this will influence silvicultural opportunities and yields).

As a result of these simple assessments, the four preliminary HrdDomMxd forest units were confirmed for planning purposes.

STEP 3

Complete the descriptions of each of the (final) current and future forest units. Include a listing of the boreal mixedwood composition type(s), ecosite(s), and broad soil group(s) in each current and future forest unit.

In this example:

The summary descriptions of the forest units are presented in Table 3. This information (e.g. composition type, broad soil group) is needed for each forest unit to work through the management interpretation tables.

Table 3. Description of current and future forest units.

Forest Unit	Composition Type(s)	Ecosite(s)*	Broad Soil Group(s)
HrdDomMxd 1a	Aspen dominated Aspen leading	ES16, ES19	boreal mixedwood coarse soils
HrdDomMxd 1b	Aspen dominated Aspen leading	ES28, ES29, ES23, ES33	boreal mixedwood medium, fine, and moist soils
HrdDomMxd 2a	Birch dominated Birch leading	ES16, ES19	boreal mixedwood coarse soils
HrdDomMxd 2b	Birch dominated Birch leading	ES28, ES29, ES23, ES33	boreal mixedwood medium, fine, and moist soils

STEP 4

For each current forest unit–stand composition type combination (from Step 3), list the future boreal mixedwood forest conditions (at canopy transition) that may be achieved through silviculture.

- silvicultural ground rules are developed for stands depleted by harvest or natural disturbance
- harvest occurs in the (late) stem exclusion, canopy transition, and gap dynamics stages of stand development

Refer to the Management Interpretation tables (Section VI)

- Begin with Table 2 in Section VI (Canopy Transition stage) and list the possible future forest composition types (future forest composition types that are not eligible are marked by an "X").
- Refer to Table 1 in Section VI (Stem Exclusion stage) and Table 3 in Section VI (Gap Dynamics stage) to refine the list of potential future forest composition types (i.e. look for differences when compared to Table 2 in Section VI [Canopy Transition]).
- If significant differences are identified between the three tables, the current condition in FMP-10 may be separated on the basis of stage of stand development.

In this example, Table 2 (from Section VI) indicates that:

- The HrdDomMxd 1a; aspen dominated current condition leads to four potential future stand conditions.
- The HrdDomMxd 1a; aspen leading current condition leads to five potential future stand conditions (see Table 4, Section VI).

A comparison between Table 2 and Tables 1 and 3 (Section VI) shows that:

- there is no difference in possible objectives for aspen dominated or aspen leading composition types when starting at canopy transition or stem exclusion (although methods and treatments may differ)
- none of the options listed for the canopy transition stage apply to the gap dynamics stage for these stand conditions

Therefore, for the current forest units in this example:

- silvicultural ground rules will be developed for stem exclusion and canopy transition stages of stand development only

Table 4. List of potential stand composition types that may be achieved through silviculture.

Current Forest Unit	Current Composition Type	Potential Future Stand Conditions
HrdDomMxd 1a	Aspen dominated →	Aspen dominated Aspen leading Softwood leading Softwood dominated
HrdDomMxd 1a	Aspen leading →	Aspen dominated Aspen leading Birch leading Softwood leading Softwood dominated

STEP 5

List the eligible silvicultural systems, methods, and treatments that may be employed to achieve the future stand condition(s) identified in Step 4.

Using Worksheet 1 (Appendix 5) list all the eligible silvicultural methods and treatments. One worksheet should be completed for each current forest composition type and will show activities leading to only one future forest composition type. As a result, more than one worksheet may be required for each current forest unit.

- consult the management interpretation tables and fact sheets to complete the table
- list all eligible methods and treatments even though some combinations of treatments and methods may not be compatible

The options on this worksheet provide the background information needed to complete the silvicultural ground rules and select a preferred treatment package. In addition, the information at the top of the worksheet may be used to record the current stand condition and desired future stand condition required for FMP-10 as follows:

- current forest unit, broad soil group(s), stand development stage(s), and current composition type may be included as part of the description of current condition in FMP-10
- future forest unit and future composition type will be included as part of the description of future condition in FMP-10

In this example:

A sample Worksheet 1 (Table 5) has been completed for the aspen dominated current stand composition type leading to the aspen leading future stand composition type. Table 5 lists the eligible methods and treatments for the desired future stand conditions (some combinations of methods and treatments may not be compatible and would not be included in one treatment package).

Table 5. A sample Worksheet 1: List of silvicultural systems and activities used to achieve the desired future stand condition.

Current Forest Unit HrdDomMxd 1a	**Future Forest Unit** HrdDomMxd 1a
Broad Soil Group boreal mixedwood coarse	
Current Stand Composition Type aspen dominated	**Future Stand Composition Type** aspen leading
Stand Development Stage(s) stem exclusion or canopy transition	

Pre-harvest Treatment	Silvicultural System	Harvest Method	Logging Method	Regeneration Treatment	Site Preparation Treatment	Tending/Cleaning Treatment	Tending/ Intermediate Stand Treatments
pre-harvest plant (CR)	clearcut	clearcut	full-tree	Pt - vegetative	manual	manual	juvenile spacing
		clearcut with standards	cut-to-length	conifers (Sw) • advance growth • pre-harvest plant (CR) • post-harvest plant • cluster planting • seed (CR) • scarification for naturals	mechanical (CR for pre-harvest plant)	chemical (R for conifer planting; CR + NR for other regeneration treatments); may be "directed" to protect hardwood component	pre-commercial thinning
					chemi-mechanical (CR for most regeneration treatments)		compositional treatment
					chemical (CR for most regeneration treatments)		commercial thinning
			tree-length		prescribed fire (CR+NR depending on conifer regeneration treatments)		

STEP 6

Select desired future stand condition(s) from Step 4.

In this example:

The following has been selected as one of the desired future stand conditions for the HrdDomMxd 1a (forest unit)/aspen dominated (stand composition type):

- future forest unit: HrdDomMxd 1a
- future stand composition type: aspen leading
- target stand composition: $\mathrm{Pt}^6\mathrm{Sw}^3\mathrm{Sb}^1$

This decision would result in the selection of silvicultural treatments to regenerate and protect the conifer component of the regenerating stand sufficient to meet the aspen leading definition.

STEP 7

Define a regeneration standard for the desired boreal mixedwood future stand condition (for a discussion on developing regeneration standards, refer to Section V).

In this example:

- Desired future forest unit is aspen leading
- Composition of an aspen leading future stand condition is:
  - $80\% > (\mathrm{Pt} + \mathrm{Bw}) \geq 50\%$, and,
  - $50\% \geq (\mathrm{Sw} + \mathrm{Sb} + \mathrm{Bf}) > 20\%$, and,
  - $\mathrm{Pt} \geq \mathrm{Bw}$
- Target future stand conditions are:
  - $\mathrm{Pt}^6\mathrm{Sw}^3\mathrm{Sb}^1$
  - Average stand diameter (Dq) for Pt = 22 cm
  - Site Index: 22
  - Rotation age: 85 years
- Approximate minimum densities at rotation:

Pt	1100 stems/ha
Sw	500 stems/ha overall
Sb	100 stems/ha

Regeneration Standard

White spruce:

- minimum 600 stems/ha at two metre spacing (in a contiguous block)
- minimum of one metre height at 10 years of age
- free-growing from potential overhead and lateral competition

Trembling aspen:

- minimum of 2000 stems/ha
- two metres height at 10 years of age
- aspen deemed acceptable if not competing with conifer stems; will be removed as competition in the areas regenerating to conifers

Black spruce:

- minimum of 100 stems/ha at two metre spacing (will be cluster planted within stand)
- minimum of one metre height at 10 years of age
- free-growing from potential overhead and lateral competition

STEP 8

From the worksheet completed in Step 5, develop suites of eligible silvicultural ground rules and treatment packages that would lead from each current stand condition to each selected future stand condition.

In this example:

Using the options listed in Worksheet 1 (Step 5), silvicultural treatment packages were developed and documented on Worksheet 2 (Table 6, below). The three silvicultural treatment packages that were developed in this example propose to harvest aspen dominated composition type of the HrdDomMxd 1a forest unit, and regenerate and tend the regenerating stand to develop into an aspen leading stand composition type by the canopy transition stage of stand development.

Table 6. A sample Worksheet 2: Constructing a silvicultural treatment package (STP) from the list of eligible activities in Table 5.

Current Forest Unit HrdDomMxd 1a	**Future Forest Unit** HrdDomMxd 1a
Broad Soil Group boreal mixedwood coarse	
Current Stand Composition Type aspen dominated	**Future Stand Composition Type** aspen leading
Stand Development Stage(s) stem exclusion or canopy transition	

Pre-harvest Treatments	Silvicultural Systems	Harvest Methods	Logging Methods	Regeneration Treatments	Site Preparation Treatments	Tending/Cleaning Treatments	Tending/ Intermediate Stand Treatments
STP 1 pre-harvest plant	clearcut	clearcut conventional	cut-to-length	aspen – vegetative advance reproduction (plant) Bf + Sb and Sw	none	manual + directed chemical	none
STP 2 none	clearcut	clearcut with standards (D)	full-tree	aspen – vegetative advance reproduction (natural) (Sb and Sw/Bf)	none	manual	compositional treatment
STP 3 none	clearcut	clearcut conventional	full-tree	aspen – vegetative spruce – cluster planting	chemi-mechanical for plant	manual + directed chemical	none

STEP 9

Identify preferred silvicultural treatment package.

- Determined by feasibility and reliability of silvicultural treatments, and an analysis of various economic, ecological, and social considerations.

In this example:

Silvicultural treatment package 2 (Table 6) was selected as the preferred option. It relies on advance growth as the method of reproducing the conifer component of the stand. With sufficient advance growth, this would be an economical approach to regenerate an aspen leading mixedwood condition. Using this approach, it is anticipated that tending and compositional treatment would be required to maintain the conifer component of the stand.

STEP 10

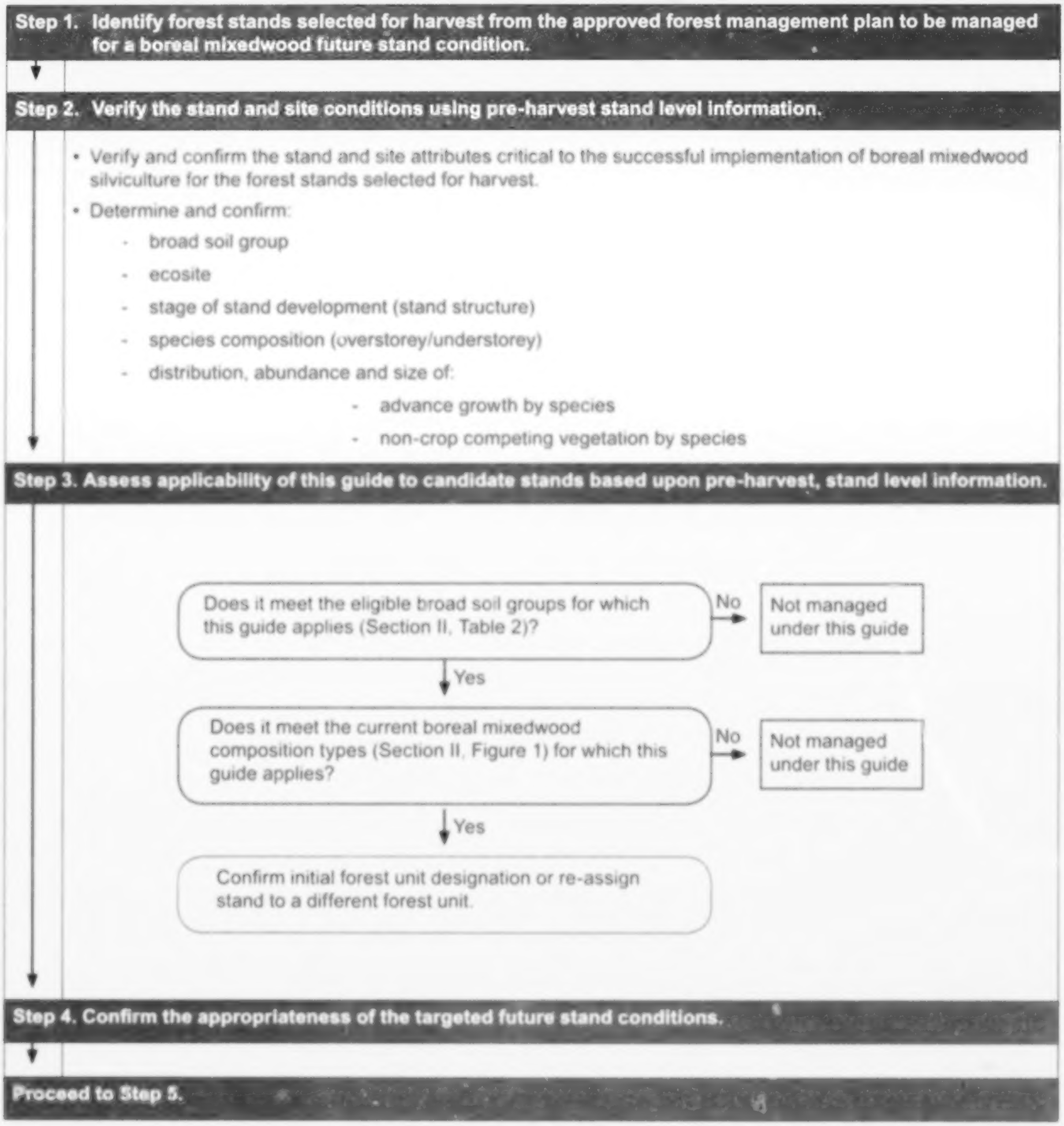
Document silvicultural ground rules for each unique combination of current stand condition and desired future stand condition (at canopy transition).

This step is completed by recording the information developed in Step 7 (regeneration standard) and Step 8 (description of current and future stand conditions and various silvicultural treatment packages) in FMP-10. The preferred silvicultural treatment package was identified in Step 9 and the other silvicultural treatment packages identified in Step 8 may be listed as alternatives.

The target future stand condition as described in FMP-10, is determined for the canopy transition stage.

If necessary, a string of silvicultural methods and treatments may be selected to harvest, regenerate, and tend a stand through various stages of stand development to direct it to the desired future stand condition (at canopy transition).

Figure 2. A flowchart showing how to apply the guide when preparing forest operations prescriptions and annual schedule of operations.



Step 1. Identify forest stands selected for harvest from the approved forest management plan to be managed for a boreal mixedwood future stand condition.

Step 2. Verify the stand and site conditions using pre-harvest stand level information.

- Verify and confirm the stand and site attributes critical to the successful implementation of boreal mixedwood silviculture for the forest stands selected for harvest.
- Determine and confirm:
  - broad soil group
  - ecosite
  - stage of stand development (stand structure)
  - species composition (overstorey/understorey)
  - distribution, abundance and size of:
    - advance growth by species
    - non-crop competing vegetation by species

Step 3. Assess applicability of this guide to candidate stands based upon pre-harvest, stand level information.

Does it meet the eligible broad soil groups for which this guide applies (Section II, Table 2)?

Does it meet the current boreal mixedwood composition types (Section II, Figure 1) for which this guide applies?

Confirm initial forest unit designation or re-assign stand to a different forest unit.

Step 4. Confirm the appropriateness of the targeted future stand conditions.

Proceed to Step 5.

Step 5. Re-evaluate the preliminary prescription for the stand presented in the approved forest management plan.

- Examine the Management Interpretation tables and fact sheets for current stand condition and desired future stand condition (at transition) to confirm the appropriateness of silvicultural systems, methods and treatments.
  - Refer to Section V: Working with the management interpretations.

Step 6. Verify conditions for the implementation of the preferred silvicultural treatment package.

- Identify the biological as well as site- and stand-specific internal and external factors affecting use of silvicultural methods and treatments (e.g. FMP objectives) based upon specific knowledge of stand and site attributes.

  e.g. worker health and safety; natural and biological factors; resources for silvicultural effectiveness monitoring and condition survey; habitat values; wood supply/product objectives; landscape consideration; forest health; markets and utilization; values and areas of concern; economic setting and financial evaluation of activities

Step 7. Confirm the forest operations prescription.

- Confirm/verify the preferred silvicultural treatment package or assign an acceptable alternative silvicultural treatment package selected from any existing and approved silvicultural ground rule that is biologically effective, economically efficient, and operationally feasible. It must conform to the conditions encountered.
- Any changes or additions during the year must be appended to the approved annual work schedule with the required certification.

Step 8. Complete additional detailed silviculture project planning for any prescribed burns or aerial broadcast herbicide.

Step 9. Prepare the annual work schedule for approval; implement.

Step 10. Monitor for silvicultural effectiveness and effects.

Example Using the Flowchart in Figure 2

STEP 1

Identify forest stands selected for harvest from the approved forest management plan to be managed for a boreal mixedwood future stand condition (Figure 2).

In this example:

The following stand was identified as eligible for harvest: $Pt^6Sp^2Bw^1Bf^1$.

Silvicultural ground rule information for this stand is:

Current Condition

Current Forest Unit: HrdDomMxd 1a
Composition Type: Aspen dominated
Broad Soil Group: Coarse
Stand Development Stage: Stem Exclusion or Canopy Transition

Future Condition

Future Forest Unit: HrdDomMxd 1a
Composition Type: Aspen leading

From FMP-10, the preferred silvicultural treatment package is:

- STP 2: clearcut, regenerate aspen vegetatively and spruce from advance growth

STEP 2

Verify the stand and site conditions using pre-harvest stand level information (Table 7).

- A pre-harvest assessment is normally required to verify these conditions.

Table 7. Key stand and site attributes to be verified.

Condition	Planning Information	Detailed Stand Information
Overstorey - Species composition	$Pt^6Sp^2Bw^1Bf^1$	$Pt^6Bf^3Bw^1$
Stand Composition Type	aspen dominated	aspen dominated
Current Forest Unit	HrdDomMxd 1a	HrdDomMxd 1a
Stage of Development	stem exclusion or canopy transition	canopy transition
Average Height	21.0	23.0
Age	70	85
Site Class	3	2
Ecosite	ES16	ES19
Broad Soil Group	boreal mixedwood coarse	boreal mixedwood coarse
Advance Regeneration	unknown	Bf – 3,500 stems/ha Sw – 250 stems/ha
Windthrow Risk	unknown	advance growth rated as "windfirm"

STEP 3

Assess applicability of this guide to candidate stands based upon pre-harvest stand level information.

From the pre-harvest stand level information, it was determined that this candidate stand is:

- species composition: $Pt^6Bf^3Bw^1$
- ecosite: ES19

Using the flowchart in Section 2, it is confirmed that these are boreal mixedwood conditions:

- a boreal mixedwood stand composition type (aspen dominated) on a boreal mixedwood site

STEP 4

Confirm the appropriateness of the targeted future stand conditions.

STEP 5

Re-evaluate the preliminary prescription for the stand presented in the approved forest management plan.

In this example:

The preferred silvicultural treatment package identified for these conditions in the forest management plan was STP 2: protection of advance growth to establish the conifer component of the regenerating stand. The pre-harvest assessment determined that there was insufficient advance growth to rely on the protection of advance growth for the regeneration of the conifer component of this stand. As a result, STP 2 was rejected and STP 3 (cluster planting) was selected (Table 8).

Table 8. The preliminary prescriptions for this stand.

STP	Pre-harvest Treatments	Silvicultural Systems	Harvest Methods	Logging Methods	Regeneration Treatments	Site Preparation Treatments	Tending/Cleaning Treatments	Tending/Intermediate Stand Treatments
1	pre-harvest plant	clearcut	clearcut conventional	cut-to-length	aspen – vegetative advance reproduction (plant) Sw and Sb +Bf **insufficient advance growth: Rejected**	none	manual + directed chemical	none
2	none	clearcut	clearcut with standards	full-tree	aspen – vegetative advance reproduction (natural) Bf + Sw and Sb **insufficient advance growth: Rejected**	none	manual	compositional thinning
3	none	clearcut	clearcut conventional	full-tree	aspen – vegetative spruce – cluster planting **Accepted**	chemi-mechanical for plant	manual + directed chemical	none

STEP 6

Verify conditions for implementation of the silvicultural treatment package.

In this example:

All conditions were satisfied to implement STP 3, so it was selected.

STEP 7

Confirm the forest operations prescription.

"The Forest Operations Prescription is the accumulation of the original silvicultural ground rule for the stand, the portions of the Annual Work Schedule (AWS) that relate to the stand (including any in-year changes that are appended to the AWS) and the signature of a Registered Professional Forester (RPF) verifying the appropriateness of the treatments. Together, these documents (along with the Annual Reports) describe the desired outcome for the stand, the activities that were originally planned, what standards are or were to be met, and what was actually implemented on the ground" (OMNR 2001).

STEP 8

Complete additional detailed silviculture project planning for any prescribed burns or aerial broadcast herbicide as required.

STEP 9

Prepare the annual work schedule for approval; Implement.

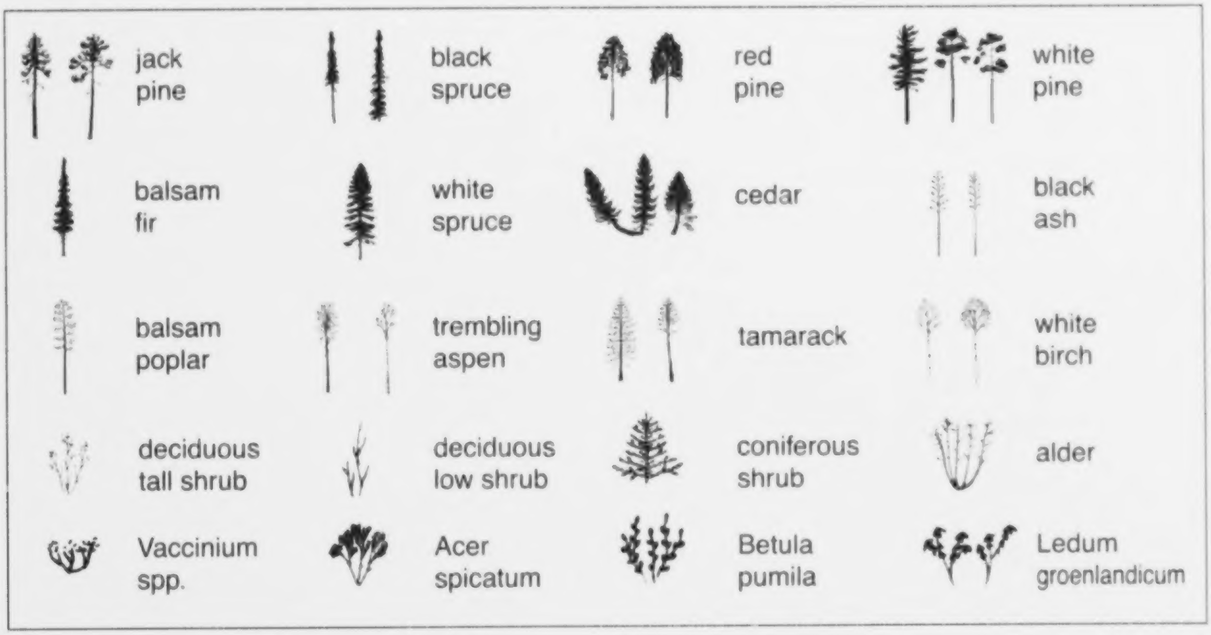
STEP 10

Monitor for silvicultural effectiveness and effects.

In addition to normal silvicultural effectiveness monitoring, rigorous coordinated monitoring of mixedwood management activities (particularly activities designated as "D", "CR", or "NR") will help improve knowledge of boreal mixedwood silviculture practices which may be included in future versions of this guide.

APPENDIX 3: NORTHWESTERN ONTARIO ECOSITE FACT SHEETS

Short Forms, Symbols, and Fill Patterns for Fact Sheets


jack pine
black spruce
red pine
white pine
balsam fir
white spruce
cedar
black ash
balsam poplar
trembling aspen
tamarack
white birch
deciduous tall shrub
deciduous low shrub
coniferous shrub
alder
Vaccinium spp.
Acer spicatum
Betula pumila
Ledum groenlandicum

Dry MR ø-1	Fresh MR 2-3	Moist to Wet MR ≥ 4	
☐ coarse	▨ coarse	■ coarse	☐ sedimentary peat
☐ coarse / loamy	▨ coarse / loamy	■ coarse / loamy	☐ fibric to humic peat
☐ fine loamy clayey	▨ fine loamy clayey	■ fine loamy clayey	☐ bedrock

Ab	Black ash	*Fraxinus nigra*
Bf	Balsam fir	*Abies balsamea*
Bw	White birch	*Betula papyrifera*
Cw	Eastern white cedar	*Thuja occidentalis*
Ew	White elm	*Ulmus americana*
Pj	Jack pine	*Pinus banksiana*
Pr	Red pine	*Pinus resinosa*
Pt	Trembling aspen	*Populus tremuloides*
Pw	White pine	*Pinus strobus*
Sb	Black spruce	*Picea mariana*
Sw	White spruce	*Picea glauca*
Ta	Tamarack	*Larix laricina*

Northwestern Ontario Ecosite Fact Sheets

Each fact sheet presents a description of the average or modal vegetation, soil/substrate, and site characteristics of an ecosite. They contain information on vegetation composition, forest structure, relationship to V-types and W-types, humus, mode of substrate deposition, landscape position, and relationship to other ecosites. The fact sheets do not represent a quantitative analysis, but rather relative abundance.

1. **Ecosite Name and Number** provide a handy index to ecosites. The ecosite numbers start at ES11 to accommodate ES1 to ES10 that have no fact sheets at this time. The name of the ecosite is derived from a vegetation component (i.e. dominant cover type) and a soil component (i.e. dominant soil texture, moisture, or depth). (See page 23, Racey *et al.* 1996).

2. **Vegetation-substrate profile** is a schematic cross-section showing typical variation in vegetation structure, parent material, depth and texture, relief and topography. The plant silhouettes represent commonly occurring species. (See page 20, Racey *et al.* 1996).

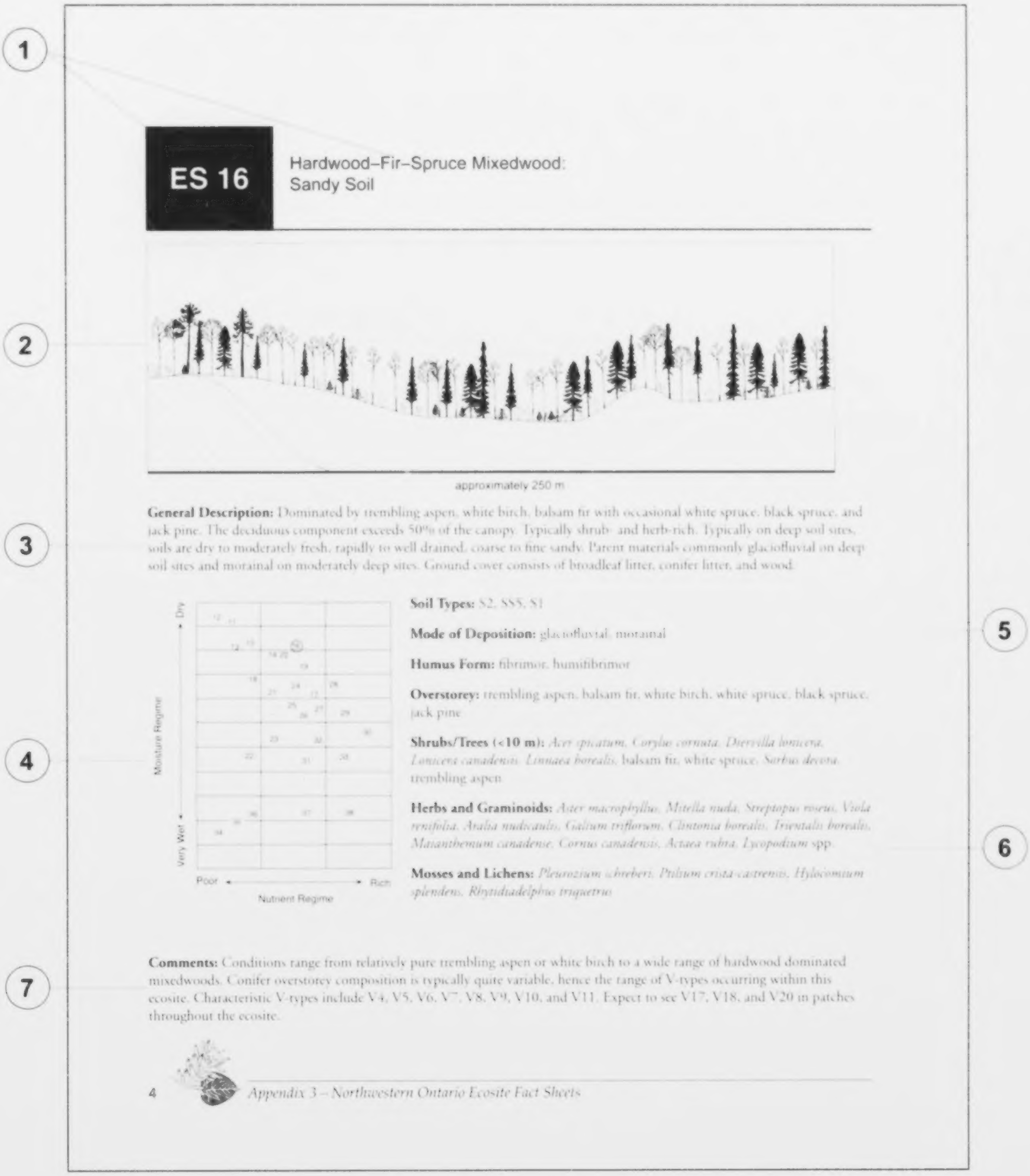
3. **General Description** is a brief account of a site's vegetation, moisture regime, soil, and site parameters. Herb- or shrub-rich/poor describes information on both species diversity and overall abundance within a stratum.

4. **Nutrient/Moisture Grid** shows the relative position of ecosites within a two-dimensional "ecological space" defined by axes representing approximate moisture and nutrient status. These axes are not calibrated to an absolute scale.

5. **Soil Types, Mode of Deposition, and Humus Form** provide a general account of the most frequently encountered conditions typical of the ecosite. Soil type names follow Sims *et al.* (1997). Mode of deposition or landform classes (e.g. lacustrine, morainal, glaciofluvial) are based on definitions in *The Canadian System of Soil Classification* (Canada Soil Survey Committee 1978).

6. **Overstorey, Shrubs/Trees, Herbs and Graminoids, Mosses and Lichens, Submergents and Floating-leaved Species.** The lists in ES11 to ES44 include those species represented in at least 40 percent of plots; those in ES46 to ES50 include species represented in at least 20 percent of plots. For all ecosites, these are the most common species in each stratum, presented in approximate order of decreasing frequency. Common names are used for tree species and scientific names for all others. Refer to Appendix I: Scientific to Common Names or Appendix II: Common to Scientific Names (Racey *et al.* 1996).

7. **Comments** provides supplementary information on vegetation, soil, variability, and relationship to other ecosites. (See *Geographic Variation and Interpretation*, page 10, Racey *et al.* 1996). V-types, W-types and S-types listed on ecosite fact sheets refer to common ecoelements expected to occur within that ecosite. They do not imply that ecoelement defines the ecosite, or that other ecoelements could not occur. Characteristic V-types refer to conditions that could comprise the entire ecosite. Inclusions are V-types or S-types that superficially appear atypical, but occur often as a relatively small proportion of the ecosite.


1
2
3
4
5
6
7
approximately 250 m
Dry
Very Wet
Moisture Regime
Poor
Rich
Nutrient Regime

ES 16 Hardwood–Fir–Spruce Mixedwood: Sandy Soil

General Description: Dominated by trembling aspen, white birch, balsam fir with occasional white spruce, black spruce, and jack pine. The deciduous component exceeds 50% of the canopy. Typically shrub- and herb-rich. Typically on deep soil sites, soils are dry to moderately fresh, rapidly to well drained, coarse to fine sandy. Parent materials commonly glaciofluvial on deep soil sites and morainal on moderately deep sites. Ground cover consists of broadleaf litter, conifer litter, and wood.

Soil Types: S2, SS5, S1

Mode of Deposition: glaciofluvial, morainal

Humus Form: fibrimor, humifibrimor

Overstorey: trembling aspen, balsam fir, white birch, white spruce, black spruce, jack pine

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Diervilla lonicera, Lonicera canadensis, Linnaea borealis*, balsam fir, white spruce, *Sorbus decora*, trembling aspen

Herbs and Graminoids: *Aster macrophyllus, Mitella nuda, Streptopus roseus, Viola renifolia, Aralia nudicaulis, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis, Actaea rubra, Lycopodium* spp.

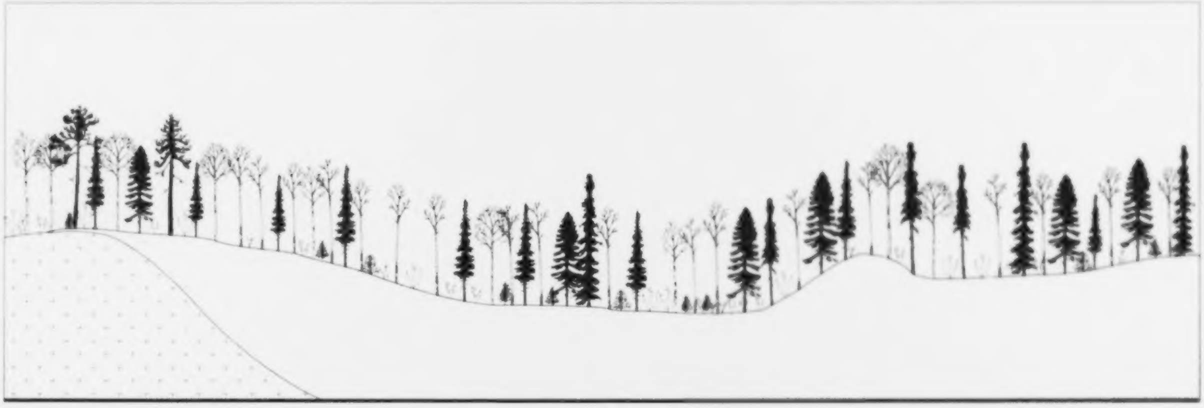
Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Rhytidiadelphus triquetrus*

Comments: Conditions range from relatively pure trembling aspen or white birch to a wide range of hardwood dominated mixedwoods. Conifer overstorey composition is typically quite variable, hence the range of V-types occurring within this ecosite. Characteristic V-types include V4, V5, V6, V7, V8, V9, V10, and V11. Expect to see V17, V18, and V20 in patches throughout the ecosite.

4 *Appendix 3 – Northwestern Ontario Ecosite Fact Sheets*

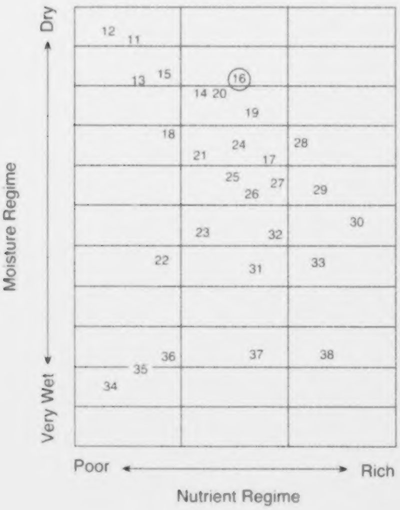
ES 16

Hardwood–Fir–Spruce Mixedwood: Sandy Soil



approximately 250 m

General Description: Dominated by trembling aspen, white birch, balsam fir with occasional white spruce, black spruce, and jack pine. The deciduous component exceeds 50% of the canopy. Typically shrub- and herb-rich. Typically on deep soil sites, soils are dry to moderately fresh, rapidly to well drained, coarse to fine sandy. Parent materials commonly glaciofluvial on deep soil sites and morainal on moderately deep sites. Ground cover consists of broadleaf litter, conifer litter, and wood.



Soil Types: S2, SS5, S1

Mode of Deposition: glaciofluvial, morainal

Humus Form: fibrimor, humifibrimor

Overstorey: trembling aspen, balsam fir, white birch, white spruce, black spruce, jack pine

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Diervilla lonicera, Lonicera canadensis, Linnaea borealis,* balsam fir, white spruce, *Sorbus decora,* trembling aspen

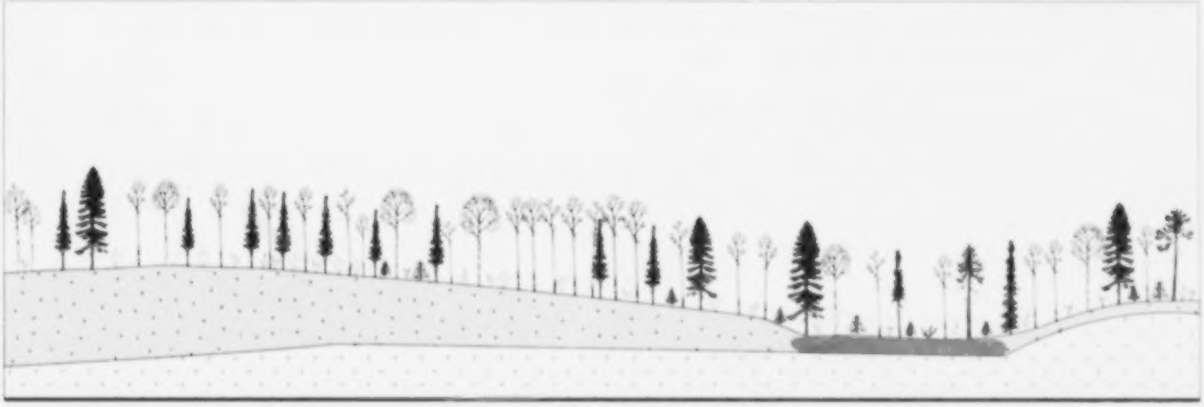
Herbs and Graminoids: *Aster macrophyllus, Mitella nuda, Streptopus roseus, Viola renifolia, Aralia nudicaulis, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis, Actaea rubra, Lycopodium* spp.

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Rhytidiadelphus triquetrus*

Comments: Conditions range from relatively pure trembling aspen or white birch to a wide range of hardwood dominated mixedwoods. Conifer overstorey composition is typically quite variable, hence the range of V-types occurring within this ecosite. Characteristic V-types include V4, V5, V6, V7, V8, V9, V10, and V11. Expect to see V17, V18, and V20 in patches throughout the ecosite.

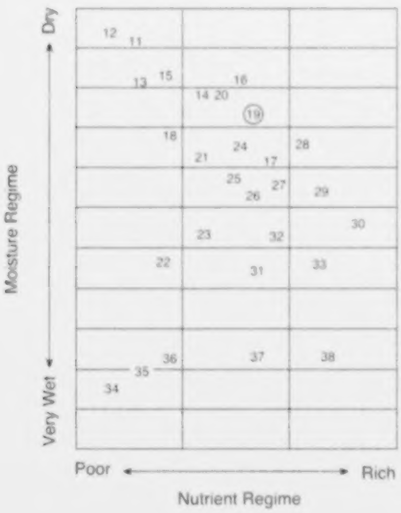
Hardwood–Fir–Spruce Mixedwood: Fresh, Sandy–Coarse Loamy Soil

ES 19



approximately 250 m

General Description: Dominated by trembling aspen, white birch, and balsam fir, with occasional occurrences of white and black spruce. Deciduous tree component exceeds 50% of the canopy. Understorey composition variable; shrub- and herb-rich. Soils are fresh, well drained, coarse loamy to fine sandy. Parent materials are commonly glaciofluvial on deep soil sites and morainal on shallow sites. Ground cover consists of broadleaf litter, conifer litter, wood, and feathermoss.



Soil Types: S3, S2, SS6, SS5, S1

Mode of Deposition: glaciofluvial, morainal

Humus Form: fibrimor, humifibrimor

Overstorey: trembling aspen, white birch, white spruce, black spruce, jack pine, balsam fir

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Diervilla lonicera, Lonicera canadensis, Linnaea borealis*, balsam fir, white spruce, *Sorbus decora*, trembling aspen

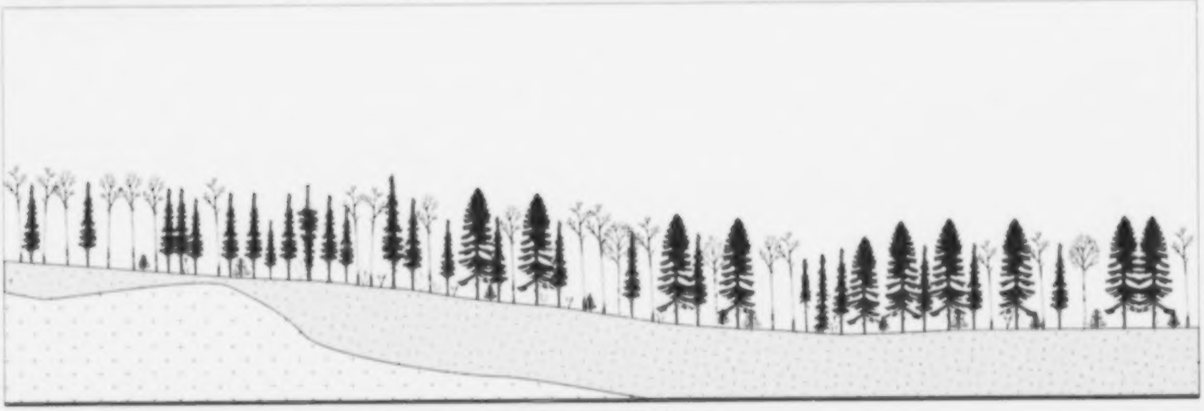
Herbs and Graminoids: *Aster macrophyllus, Aralia nudicaulis, Mitella nuda, Streptopus roseus, Viola renifolia, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis, Actaea rubra*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Rhytidiadelphus triquetrus*

Comments: Conifer component of overstorey typically quite variable. Characteristic V-types include V4, V5, V6, V7, V8, V9, V10, and V11. Expect to see pockets of V1 or V2 in lower areas, grading to V14, V15, and V17 as conifer concentration increases locally. May include tolerant hardwoods such as yellow birch, red maple and sugar maple in Site Regions 4S, 4W and 5S.

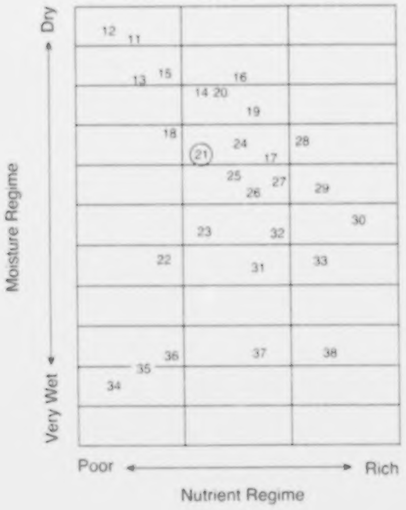
ES 21

Fir–Spruce Mixedwood: Fresh, Coarse Loamy Soil



approximately 250 m

General Description: Dominated by balsam fir, white spruce, and black spruce with mixtures of trembling aspen and white birch. Coniferous component exceeds 50% of the canopy. Typically shrub- and herb-poor with abundant feathermoss; *Acer spicatum* may be locally abundant. Soils fresh, well drained, coarse loamy. Occurring predominantly on morainal and glaciofluvial material. Ground cover consists of broadleaf litter, feathermoss, conifer, and wood.



Soil Types: S3, SS6

Mode of Deposition: morainal, glaciofluvial

Humus Form: fibrimor, humifibrimor

Overstorey: balsam fir, white spruce, black spruce, trembling aspen, white birch

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Diervilla lonicera, Lonicera canadensis, Rubus pubescens, Linnaea borealis,* balsam fir, white birch, trembling aspen

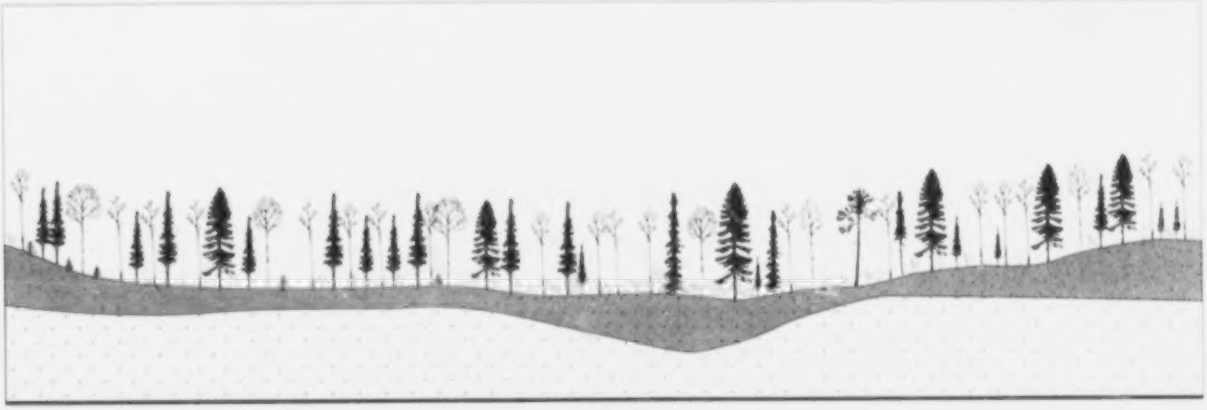
Herbs and Graminoids: *Aster macrophyllus, Streptopus roseus, Aralia nudicaulis, Viola renifolia, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Rhytidiadelphus triquetrus*

Comments: Extremely variable and dynamic ecosite in terms of forest cover. Characteristic V-types include V14, V15, V16, and V19 but expect to encounter V24 and V25 in patches. Spruce budworm drives many aspects of stand dynamics. This ecosite may also occur on toe and lower slope positions with S2 and occasionally S1 soils. May include tolerant hardwoods such as yellow birch, red maple, and sugar maple in Site Regions 4S, 4W and 5S.

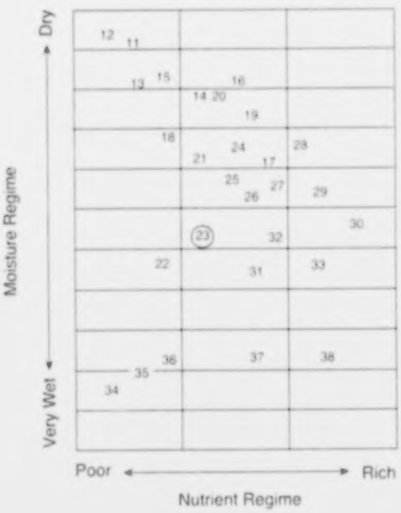
Hardwood–Fir–Spruce Mixedwood: Moist, Sandy–Coarse Loamy Soil

ES 23



approximately 250 m

General Description: Dominated by trembling aspen, white birch, balsam fir and occasional occurrence of white spruce, black spruce and jack pine. Deciduous tree component exceeds 50% of the canopy. Moderately shrub- and herb-rich. Soils are moist, sandy to coarse loamy. Occurring predominantly on morainal, glaciofluvial and occasionally lacustrine parent material. Ground cover consists of broadleaf litter, conifer litter, feathermoss, and occasional patches of *Sphagnum*.



Soil Types: S7, S8, SS8

Mode of Deposition: morainal, glaciofluvial

Humus Form: humifibrimor, fibrimor

Overstorey: white birch, trembling aspen, balsam fir, white spruce, black spruce, jack pine, balsam poplar

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Rubus pubescens, Sorbus decora, Linnaea borealis,* balsam fir, trembling aspen

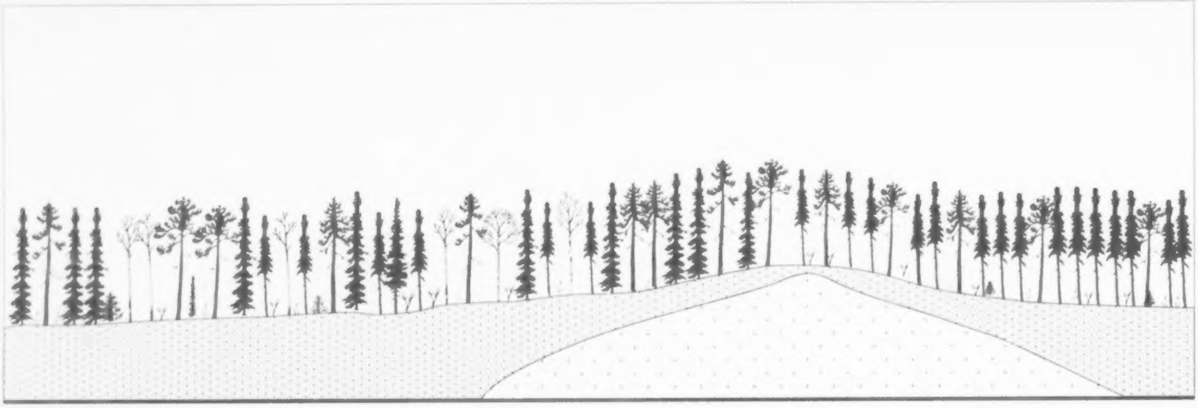
Herbs and Graminoids: *Aster macrophyllus, Streptopus roseus, Aralia nudicaulis, Viola renifolia, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis*

Comments: This ecosite typically occurs on lower slopes in rolling terrain. Characteristic V-types include V1, V5, V6, V7, V8, and V9 but expect to see V14 and V19 in patches. Often associated with lower and toe slope positions. May contain tolerant hardwoods such as yellow birch and red maple in Site Regions 4S, 4W, and 5S.

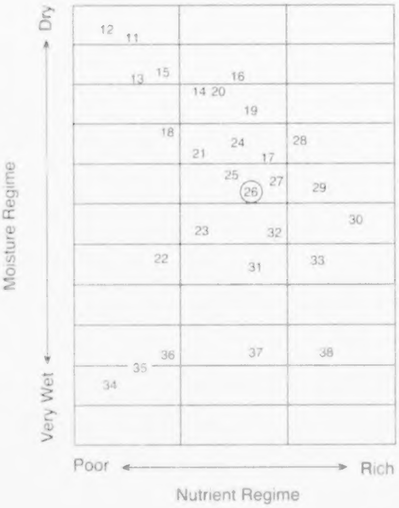
ES 26

Spruce–Pine / Feathermoss: Fresh, Fine Loamy–Clayey Soil



approximately 250 m

General Description: Overstorey dominated by black spruce and jack pine. Occasionally has scattered occurrences of trembling aspen, white birch, and balsam fir. Typically shrub- and herb-poor. Soils fresh, well to moderately well drained, fine loamy–clayey; developed primarily on lacustrine parent material. Ground cover consists of feathermoss, conifer litter, and wood.



Soil types: S5, S6, SS7

Mode of Deposition: lacustrine, morainal

Humus Form: fibrimor, humifibrimor

Overstorey: black spruce, jack pine, balsam fir, trembling aspen, white birch, white spruce

Shrubs/Trees (<10 m): *Ledum groenlandicum, Gaultheria hispidula,* black spruce, *Vaccinium myrtilloides, Vaccinium angustifolium, Linnaea borealis,* balsam fir, *Rosa acicularis, Diervilla lonicera, Rubus pubescens*

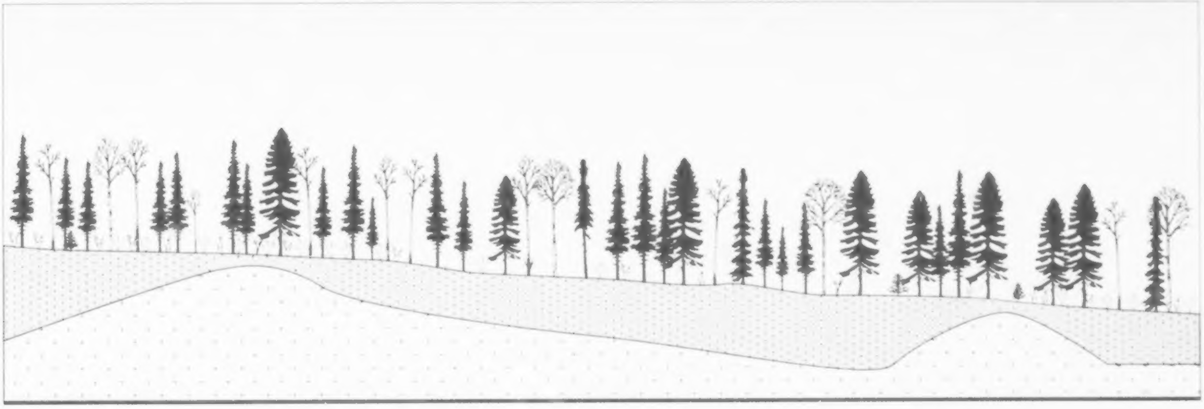
Herbs and Graminoids: *Clintonia borealis, Coptis trifolia, Maianthemum canadense, Cornus canadensis, Petasites frigidus*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Dicranum polysetum*

Comments: Relatively complex ecosite with characteristic V-types including V20, V31, V32, and V33. Expect V17 and V19 to provide shrub- and herb-rich phases, and V36 and V34 on toe slopes and depressions. Soils generally deep but may often have inclusions of SS9 peaty phase soils. May occur as a complex with ES31 in rolling or broken terrain with impeded drainage.

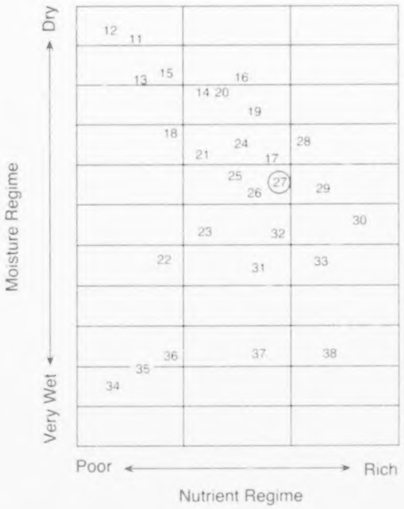
Fir–Spruce Mixedwood: Fresh, Silty–Fine Loamy Soil

ES 27



approximately 250 m

General Description: Dominated by balsam fir, black spruce and white spruce with mixtures of trembling aspen and white birch. Typically shrub- and herb-rich. Soils are fresh, well to moderately well drained, silty to fine loamy. Occurring predominantly on lacustrine and glaciofluvial parent material. Ground cover consists of broadleaf litter, conifer litter, feathermoss, and wood.



Soil Types: S4, S5, SS7

Mode of Deposition: lacustrine, glaciofluvial

Humus Form: fibrimor, humifibrimor

Overstorey: balsam fir, white spruce, black spruce, trembling aspen, white birch

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Diervilla lonicera, Lonicera canadensis, Rubus pubescens, Linnaea borealis,* balsam fir, white birch, trembling aspen

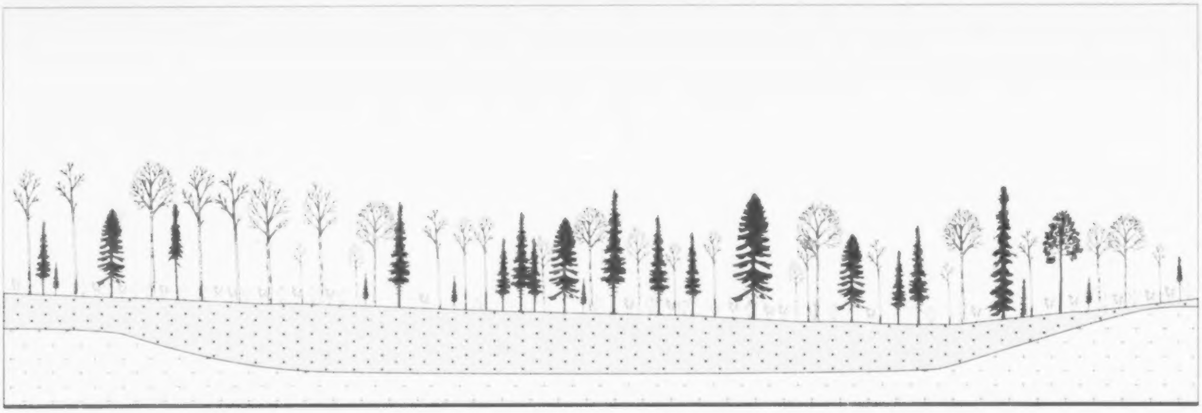
Herbs and Graminoids: *Aster macrophyllus, Streptopus roseus, Aralia nudicaulis, Viola renifolia, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Rhytidiadelphus triquetrus*

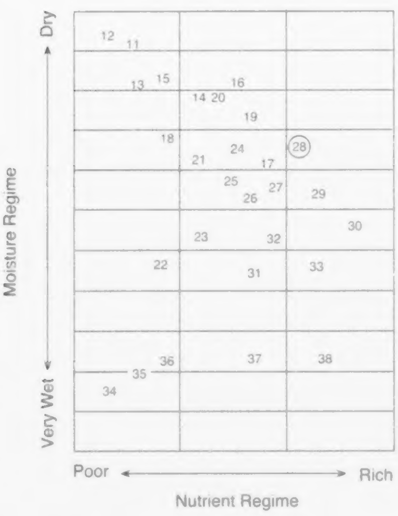
Comments: Vegetation cover is relatively uniform, consisting of characteristic V-types V14, V15, and V16. Expect local variation to V7, V8, V9, V24, and V25 where hardwood pockets are encountered. May also contain pockets of V12 and V13 in Site Regions 4S, 4W, and 5S. Soils are typically deep, but may contain inclusions of SS7. Topography is often gently rolling.

ES 28

Hardwood–Fir–Spruce Mixedwood: Fresh, Silty Soil



General Description: Dominated by trembling aspen and white birch with occasional occurrences of balsam fir, black spruce, jack pine and white spruce. Deciduous tree component exceeds 50% of the canopy. Shrub- and herb-rich. Soils fresh, well to moderately well drained silt or silt loam. Developed on lacustrine and glaciofluvial parent material. Ground cover consists of broadleaf litter, conifer litter, feathermoss, and wood.



Soil Types: S4, SS7

Mode of Deposition: lacustrine, glaciofluvial

Humus Form: fibrimor, humifibrimor

Overstorey: trembling aspen, balsam fir, white birch, white spruce, jack pine, black spruce

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Diervilla lonicera, Lonicera canadensis, Linnaea borealis, Rubus pubescens, Alnus viridis, Vaccinium* spp., *Rosa acicularis,* balsam fir, white spruce, *Sorbus decora,* white birch, trembling aspen

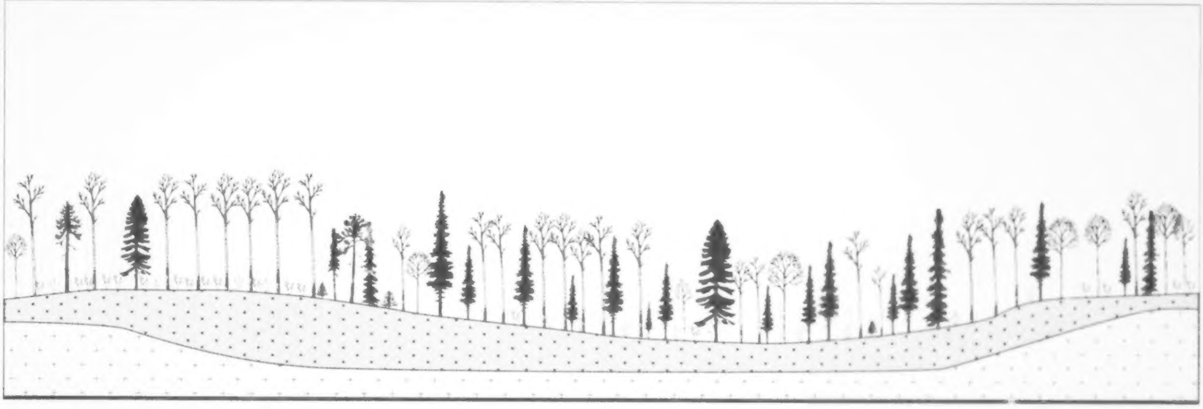
Herbs and Graminoids: *Aster macrophyllus, Mitella nuda, Streptopus roseus, Aralia nudicaulis, Viola renifolia, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis, Actaea rubra, Lycopodium* spp.

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Rhytidiadelphus triquetrus*

Comments: Extremely variable and productive ecosite. Characteristic V-types include V4, V5, V6, V7, V8, V9, V10, and V11, with some or all V-types being present on one site. Expect grading to V14 and V15 in patches with more abundant conifer cover. Landforms range from gently rolling to level terrain.

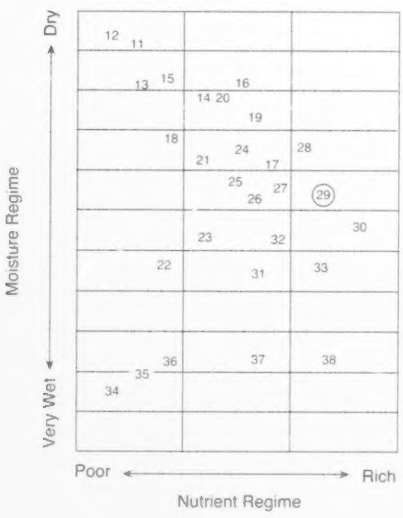
Hardwood–Fir–Spruce Mixedwood: Fresh, Fine Loamy–Clayey Soil

ES 29



approximately 250 m

General Description: Dominated by trembling aspen and occasionally white birch, with a conifer mix of balsam fir, white spruce, black spruce, and occasionally jack pine. Deciduous trees comprise more than 50% of the canopy. Shrub- and herb-rich. Soils fresh, moderately well to well drained, fine loamy–clayey. Developed primarily on lacustrine parent material. Ground cover consists of broadleaf litter, conifer litter, feathermoss, and wood.



Soil Types: S5, S6, SS7

Mode of Deposition: lacustrine

Humus Form: fibrimor, humifibrimor

Overstorey: trembling aspen, balsam fir, white spruce, black spruce, white birch, jack pine, balsam poplar

Shrubs/Trees (<10 m): *Acer spicatum, Corylus cornuta, Cornus stolonifera, Viburnum edule, Ribes triste, Diervilla lonicera, Lonicera canadensis, Linnaea borealis,* balsam fir, *Sorbus decora,* trembling aspen

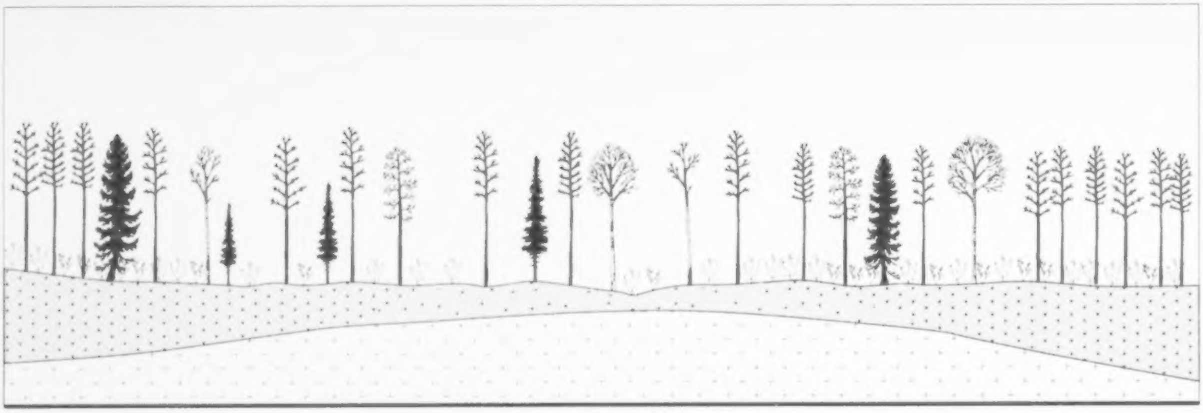
Herbs and Graminoids: *Aster macrophyllus, Fragaria virginiana, Aralia nudicaulis, Streptopus roseus, Viola renifolia, Anemone quinquefolia, Galium triflorum, Clintonia borealis, Trientalis borealis, Maianthemum canadense, Cornus canadensis, Mitella nuda*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens*

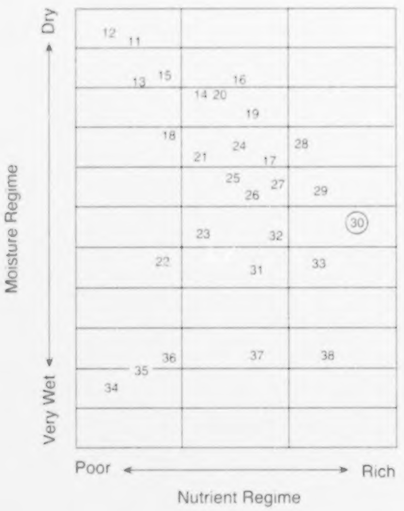
Comments: Plant species composition varies slightly from ES28 as a result of occurring on the finer-textured parent material. Characteristic V-types V4, V5, V6, V7, V8, and V9 occur frequently; V10 and V11 occasionally. Expect to encounter V14 and V16 in local patches and rarely V1, V12, and V13. Yellow birch, red maple, and large-toothed aspen may also occur in Site Regions 4S, 4W and 5S. Apart from the listed S-types, some localities may have small (< 10% area) inclusions of SS2 and SS3.

ES 30

Black Ash Hardwood: Fresh, Silty–Clayey Soil


approximately 250 m

General Description: Dominated by black ash with occurrences of trembling aspen, white birch, balsam poplar, and white cedar. Shrub- and herb-rich. Soils fresh to moist, well to imperfectly drained, silty to clayey textured. Predominantly on lacustrine parent materials. Ground cover consists of broadleaf litter, graminoid litter, feathermoss, and wood.



Soil Types: S5, S6, S10, S4

Mode of Deposition: lacustrine

Humus Form: humifibrimor, fibrimor, mull

Overstorey: black ash, trembling aspen, white birch, balsam poplar, white cedar

Shrubs/Trees (<10 m): balsam fir, *Rubus pubescens, Amelanchier* spp., *Prunus virginiana, Rubus idaeus, Lonicera canadensis, Ribes triste, Acer spicatum, Corylus cornuta, Ribes hirtellum*

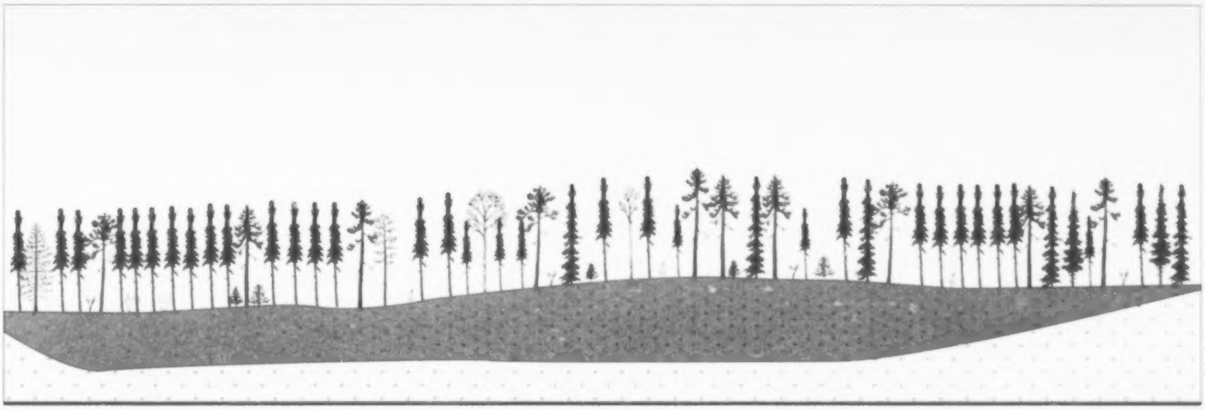
Herbs and Graminoids: *Aralia nudicaulis, Equisetum sylvaticum, Maianthemum canadense, Aster macrophyllus, Fragaria virginiana, Streptopus roseus, Cinna latifolia, Dryopteris carthusiana, Athyrium filix-femina, Circaea alpina, Galium triflorum, Mitella nuda*

Mosses and Lichens: *Drepanocladus* spp., *Climacium dendroides, Thuidium* spp.

Comments: Ecosite is characteristically found in subdued topography and depressions. Often associated with fine-textured soils and small intermittent watercourses. Transitions to SS9 and S11 peaty-phase soils are common. Characteristic V-type is V2, but V1 and V22 also occur. A wide variety of other vegetative conditions may occur, occasionally including red maple in Site Regions 4S, 4W, and 5S. Grades to ES38 on alluvial plains and low-lying areas adjacent to lakes.

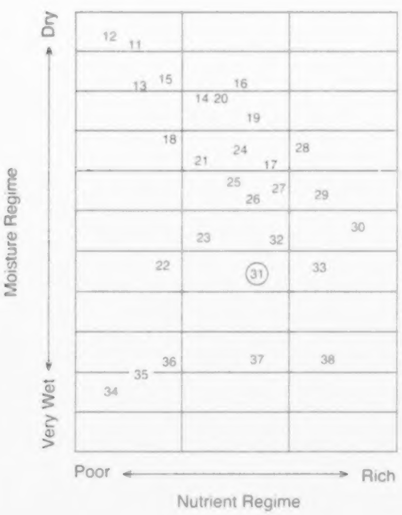
Spruce–Pine / Feathermoss: Moist, Silty–Clayey Soil

ES 31



approximately 250 m

General Description: Overstorey dominated by black spruce and jack pine. Scattered occurrences of trembling aspen, white birch, balsam poplar, white spruce, and balsam fir. Shrub- and herb-poor. Soils moist, silty to clayey textured. Developed primarily on lacustrine parent materials. Ground cover consists of feathermoss, conifer litter, and wood, with *Sphagnum* patches in wetter locations.



Soil Types: S9, S10, SS7, SS8

Mode of Deposition: lacustrine, morainal

Humus Form: fibrimor, humifibrimor

Overstorey: black spruce, jack pine, trembling aspen, white birch, balsam poplar, balsam fir, white spruce

Shrubs/Trees (<10 m): black spruce, balsam fir, *Alnus incana, Rubus pubescens, Vaccinium* spp., *Gaultheria hispidula, Ledum groenlandicum*

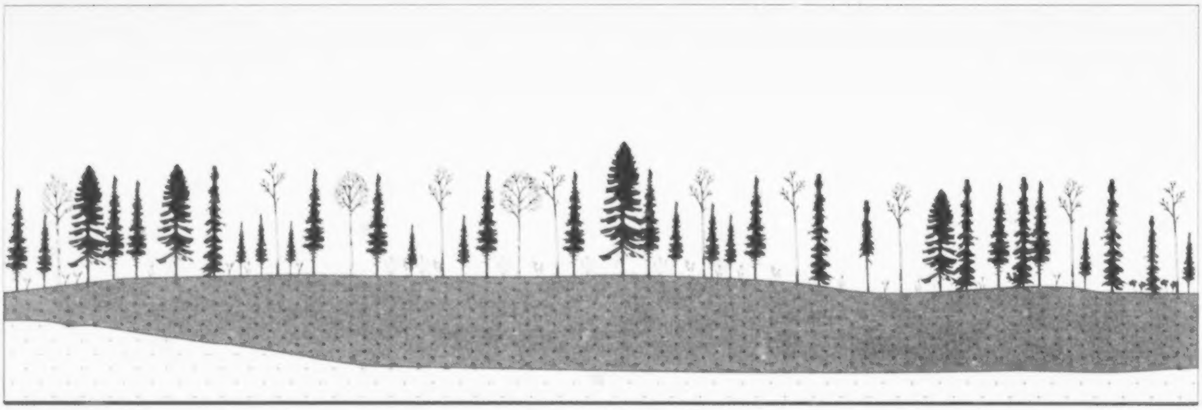
Herbs and Graminoids: *Clintonia borealis, Aralia nudicaulis, Coptis trifolia, Maianthemum canadense, Cornus canadensis*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Sphagnum girgensohnii*

Comments: Relatively uniform ecosite consisting of characteristic V-types V31, V32, and V33. Grades to V34 on toe slopes and depressions, often reflecting a telluric influence. Moister soil conditions contribute to a more diverse overstorey. Expect V34 where ecosite grades with ES35, or ES36 and V19, and V20 where occasional patches of hardwood occur. Soils grade to peaty phase S11 and SS9.

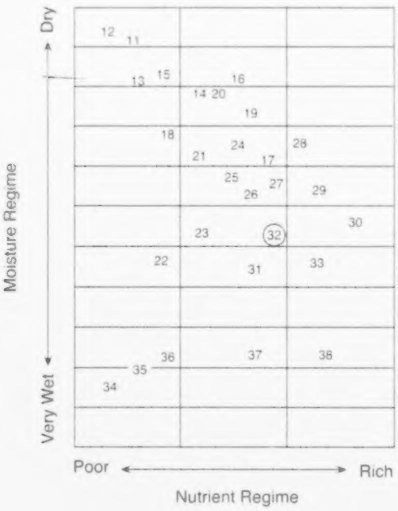
ES 32

Fir–Spruce Mixedwood: Moist, Silty–Clayey Soil



approximately 250 m

General Description: Dominated by balsam fir, white spruce, trembling aspen, and black spruce. Occasionally with white birch, jack pine, and balsam poplar. Conifer component exceeds 50%. Moderately shrub- and herb-rich. Soils moist, silty to clayey. Developed primarily on lacustrine parent materials. Ground cover consists of broadleaf litter, conifer litter, feathermoss, and wood.



Soil Types: S9, S10, SS8

Mode of Deposition: lacustrine, glaciofluvial

Humus Form: fibrimor, humifibrimor

Overstorey: balsam fir, white spruce, trembling aspen, black spruce, jack pine, white birch, balsam poplar

Shrubs/Trees (<10 m): *Rubus pubescens, Linnaea borealis,* balsam fir, *Diervilla lonicera, Acer spicatum, Corylus cornuta, Alnus incana, Rosa acicularis, Ledum groenlandicum*

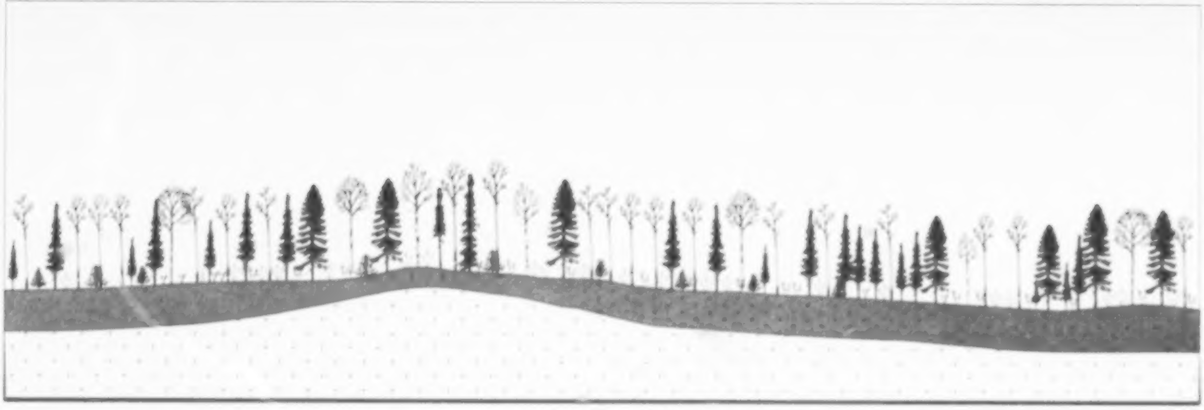
Herbs and Graminoids: *Aralia nudicaulis, Streptopus roseus, Clintonia borealis, Coptis trifolia, Mitella nuda, Aster macrophyllus, Maianthemum canadense, Cornus canadensis*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis, Sphagnum girgensohnii*

Comments: Overstorey composition variable. Characteristic V-types V14, V15, and V19 tend to be intermixed in some areas and relatively pure in others. Expect V22 to occur on rich sites in the vicinity of Atikokan, Fort Frances, and Dryden. Soils often grade to peaty phase S11, or moderately deep organic SS9 in association with ES35, ES36, and ES37.

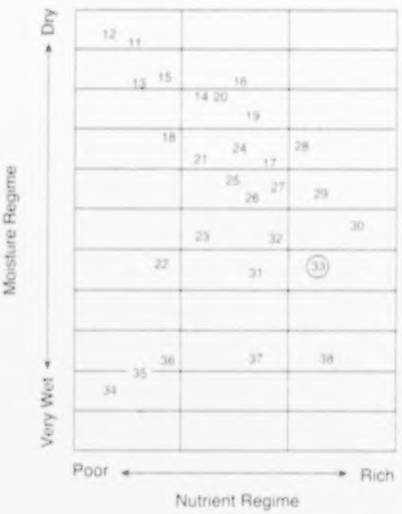
Hardwood–Fir–Spruce Mixedwood: Moist, Silty–Clayey Soil

ES 33



approximately 250 m

General Description: Dominated by trembling aspen, white birch, balsam fir, and white spruce. Occasionally with black spruce and balsam poplar. Conifer component less than 50%. Moderately shrub- and herb-rich. Soils moist, imperfectly to poorly drained, silty to clayey textured. Developed primarily on lacustrine parent materials. Ground cover consists of broadleaf litter, conifer litter, and wood.



Soil Types: S9, SS8, S10

Mode of Deposition: lacustrine, glaciofluvial

Humus Form: fibrimor, humifibrimor

Overstorey: trembling aspen, balsam fir, white spruce, white birch, balsam poplar, black spruce

Shrubs/Trees (<10 m): *Rubus pubescens, Sorbus decora,* balsam fir, *Acer spicatum, Corylus cornuta, Alnus incana, Rosa acicularis, Actaea rubra, Viburnum edule, Rubus idaeus, Ribes triste*

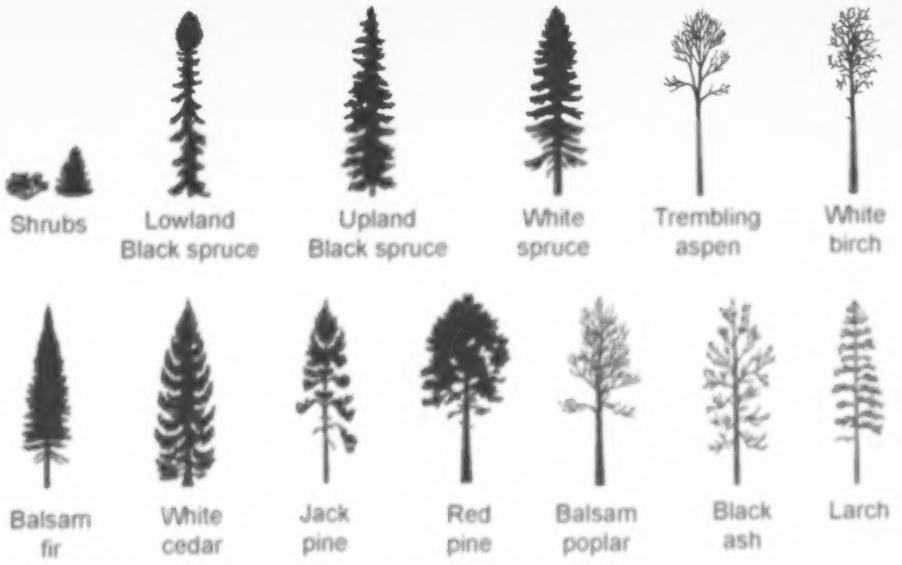
Herbs and Graminoids: *Aralia nudicaulis, Mertensia paniculata, Streptopus roseus, Clintonia borealis, Trientalis borealis, Mitella nuda, Maianthemum canadense, Cornus canadensis, Cinna latifolia, Dryopteris carthusiana, Gymnocarpium dryopteris, Petasites frigidus, Equisetum sylvaticum, Galium triflorum*

Mosses and Lichens: *Pleurozium schreberi, Ptilium crista-castrensis*

Comments: Ecosite features characteristic V-types V5, V6, V7, V8, V9, and occasionally V4, but expect to encounter V1 and V2 in isolated patches or in depressions. Topography is typically subdued and low. May be early successional stage of ES32.

APPENDIX 4: NORTHEASTERN ONTARIO ECOSITE FACT SHEETS

Symbols for Northeastern Ontario Ecosite Fact Sheets


Shrubs
Lowland Black spruce
Upland Black spruce
White spruce
Trembling aspen
White birch
Balsam fir
White cedar
Jack pine
Red pine
Balsam poplar
Black ash
Larch

Organic Horizons

L ┆
F ▤
H ■
Hi ■
Of ▥
Om ▥
Oh ▩

Mineral Soil Horizons

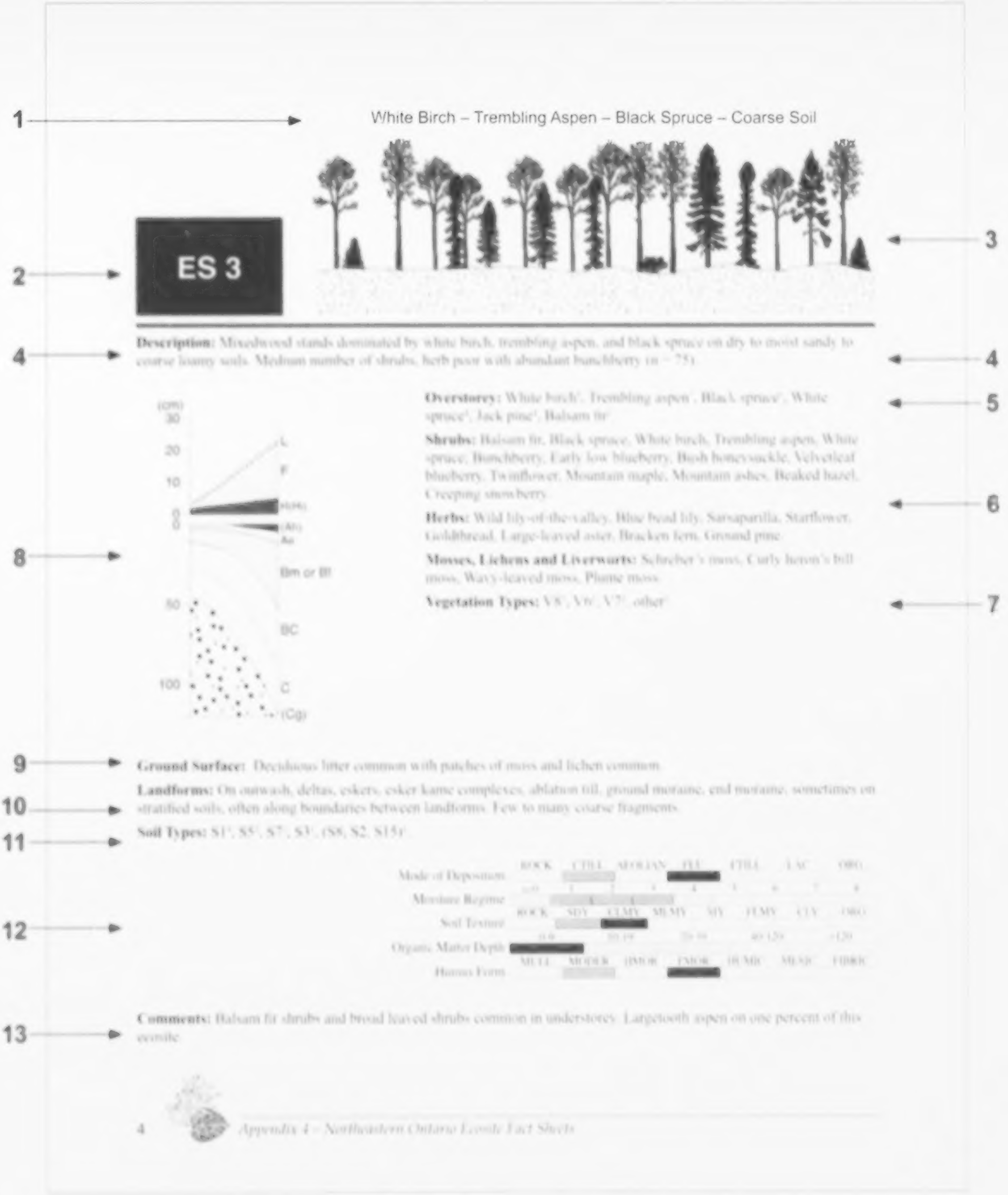
Ah ■
Bm □
Bt ▤
C/Ck □
Ae □
Bf □
BC □

Mottles and Gley

g (mottles) ⁘
Bedrock ▩
G (gley) ▤
Coarse fragments ○

Ecosite Fact Sheet Explanation

1. **Ecosite Name:** a name chosen to highlight the distinctive vegetation and soil features of an ecosite.
2. **Ecosite Number:** provides a quick reference. Ecosites with the same number have similar characteristics. The f, m and c subscripts indicate a gradient of increasingly coarse soil (f = fine soil, m = medium soil, c = coarse soil). The p and r subscripts indicate a gradient of increasing richness (p = species poor, r = species rich).
3. **Stand Structure Silhouette:** a representation of the composition and structure of a typical ecosite cross section.
4. **Description:** a general text description indicating the dominant overstorey, understorey and soil characteristics. Sample sizes are shown in brackets.
5. **Overstorey:** a listing of the tree species, ranked by frequency of occurrence in the sample (e.g. black spruce^{7} indicates that black spruce occurred in 70 percent of the samples).
6. **Understorey (Shrubs, Herbs, Mosses, Lichens and Liverworts):** a listing of the shrubs, herbs, mosses, lichens and liverworts in descending order of frequency. Tree shrubs are separated from other shrubs by a semi-colon. All the species listed occurred on more than 40 percent of the plots. Herbs include ferns, fern allies, grasses, and sedges.
7. **Vegetation Types:** a listing of the vegetation types, ranked by frequency of occurrence in the sample (e.g. V2^{8} indicates that vegetation type 2 occurred in 80 percent of the samples).
8. **Soil Profile:** a cross sectional diagram, showing the typical sequence of horizons and their range in thickness. Note that the scale used for the forest floor is larger than that used for the mineral soil.
9. **Ground Surface:** a general description of surface materials, microtopography, and typical materials of the forest floor.
10. **Landforms:** a listing of the landforms upon which the ecosites commonly occur.
11. **Soil Types:** a listing of the soil types, ranked by frequency of occurrence in the sample (e.g. S1^{7} indicates that soil type S1 occurred in 70 percent of the samples).
12. **Soil Feature Histograms (Moisture Regime, Soil Texture, Organic Matter Depth, Humus Form and Mode of Deposition):** a visual representation of the frequency of occurrence in the sample, of these soil features. Darker = more frequent.
13. **Comments:** a description of additional characteristics or unique features.


1
2
3
4
4
5
6
7
8
9
10
11
12
13
(cm)
30
20
10
0
0
50
100
L
F
H(Ah)
(Ah)
Ae
Bm or Bf
BC
C
(Cg)
ROCK
CTILL
AEOLIAN
FLU
FTILL
LAC
ORG
Mode of Deposition
0
1
2
3
4
5
6
7
8
Moisture Regime
ROCK
SDY
CLMY
MLMY
SIY
FLMY
CLY
ORG
Soil Texture
0-9
10-19
20-39
40-120
>120
Organic Matter Depth
MULL
MODER
HMOR
FMOR
HUMIC
MESIC
FIBRIC
Humus Form

White Birch – Trembling Aspen – Black Spruce – Coarse Soil

ES 3

Description: Mixedwood stands dominated by white birch, trembling aspen, and black spruce on dry to moist sandy to coarse loamy soils. Medium number of shrubs, herb poor with abundant bunchberry (n = 75).

Overstorey: White birch, Trembling aspen, Black spruce, White spruce, Jack pine, Balsam fir

Shrubs: Balsam fir, Black spruce, White birch, Trembling aspen, White spruce, Bunchberry, Early low blueberry, Bush honeysuckle, Velvetleaf blueberry, Twinflower, Mountain maple, Mountain ashes, Beaked hazel, Creeping snowberry

Herbs: Wild lily-of-the-valley, Blue bead lily, Sarsaparilla, Starflower, Goldthread, Large-leaved aster, Bracken fern, Ground pine

Mosses, Lichens and Liverworts: Schreber's moss, Curly heron's bill moss, Wavy-leaved moss, Plume moss

Vegetation Types: V8, V6, V7, other

Ground Surface: Deciduous litter common with patches of moss and lichen common.

Landforms: On outwash, deltas, eskers, esker kame complexes, ablation till, ground moraine, end moraine, sometimes on stratified soils, often along boundaries between landforms. Few to many coarse fragments.

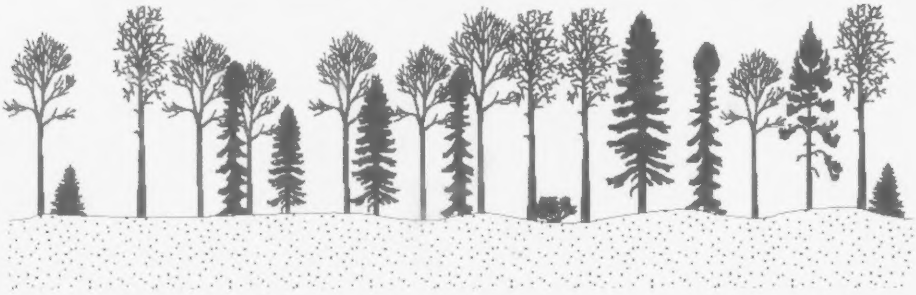
Soil Types: S1, S5, S7, S3, (S8, S2, S15)

Comments: Balsam fir shrubs and broad leaved shrubs common in understorey. Largetooth aspen on one percent of this ecosite.

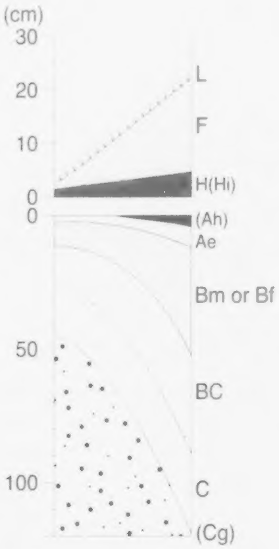
4 *Appendix 4 – Northeastern Ontario Ecosite Fact Sheets*

ES 3

White Birch – Trembling Aspen – Black Spruce – Coarse Soil



Description: Mixedwood stands dominated by white birch, trembling aspen, and black spruce on dry to moist sandy to coarse loamy soils. Medium number of shrubs, herb poor with abundant bunchberry (n = 75).



Overstorey: White birch^{8}, Trembling aspen^{7}, Black spruce^{6}, White spruce^{4}, Jack pine^{4}, Balsam fir^{2}.

Shrubs: Balsam fir, Black spruce, White birch, Trembling aspen, White spruce; Bunchberry, Early low blueberry, Bush honeysuckle, Velvetleaf blueberry, Twinflower, Mountain maple, Mountain ashes, Beaked hazel, Creeping snowberry.

Herbs: Wild lily-of-the-valley, Blue bead lily, Sarsaparilla, Starflower, Goldthread, Large-leaved aster, Bracken fern, Ground pine.

Mosses, Lichens and Liverworts: Schreber's moss, Curly heron's bill moss, Wavy-leaved moss, Plume moss.

Vegetation Types: V8^{5}, V6^{2}, V7^{2}, other^{1}.

Ground Surface: Deciduous litter common with patches of moss and lichen common.

Landforms: On outwash, deltas, eskers, esker/kame complexes, ablation till, ground moraine, end moraine; sometimes on stratified soils, often along boundaries between landforms. Few to many coarse fragments.

Soil Types: S1^{4}, S5^{2}, S7^{2}, S3^{1}, (S8, S2, S15)^{1}.

	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG
Mode of Deposition		▨		■			

	0-0	1	2	3	4	5	6	7	8
Moisture Regime		▨	▨	▨					

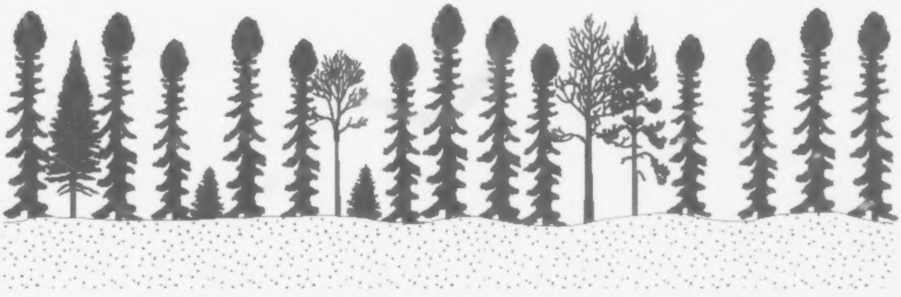
	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG
Soil Texture		▨	■					

	0-9	10-19	20-39	40-120	>120
Organic Matter Depth	■				

	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC
Humus Form		▨		■			

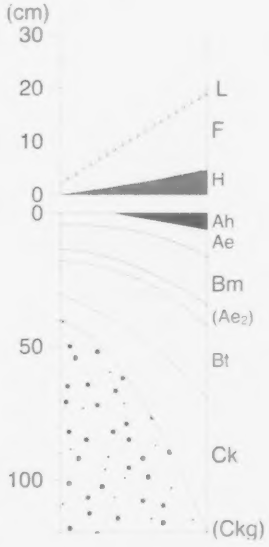
Comments: Balsam fir shrubs and broad leaved shrubs common in understorey. Largetooth aspen on one percent of this ecosite.

Black Spruce – Fine Soil



ES 5f

Description: Conifer stands dominated by black spruce on fresh to moist, fine loamy to clayey soils. Shrub and herb poor, with abundant feathermoss (n = 35).



Overstorey: Black spruce^{10}, Balsam fir^{2}, Jack pine^{2}, White birch^{1}, Balsam poplar^{1}.

Shrubs: Jack pine, Balsam fir; Creeping snowberry, Bunchberry, Twinflower, Velvetleaf blueberry, Labrador-tea, Early low blueberry, Dwarf raspberry, Bristly wild rose.

Herbs: Goldthread, Wild lily-of-the-valley, Sweet coltsfoot, Blue bead lily, Woodland horsetail.

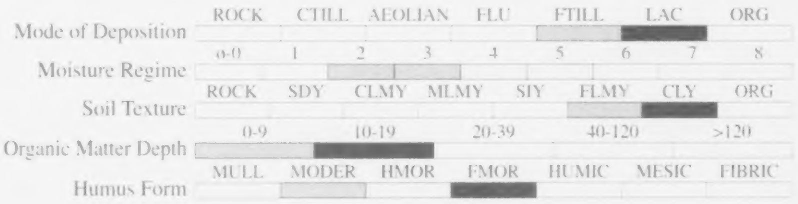
Mosses, Lichens and Liverworts: Schreber's moss, Plume moss, Stair-step moss, Wavy-leaved moss, Reindeer lichen, Lady's tresses peat moss, Curly heron's bill moss, False pixie cup, Powder horn lichen.

Vegetation Types: V23^{3}, V24^{2}, V20^{1}, V15^{1}, (V8, V16)^{1}, (V22, V26)^{1}, other^{1}.

Ground Surface: Usually a continuous carpet of feathermoss with pockets of *Sphagnum* abundant and patches of conifer litter.

Landforms: Glaciolacustrine or clay till plains, and undulating drumlinoid formations. Few coarse fragments.

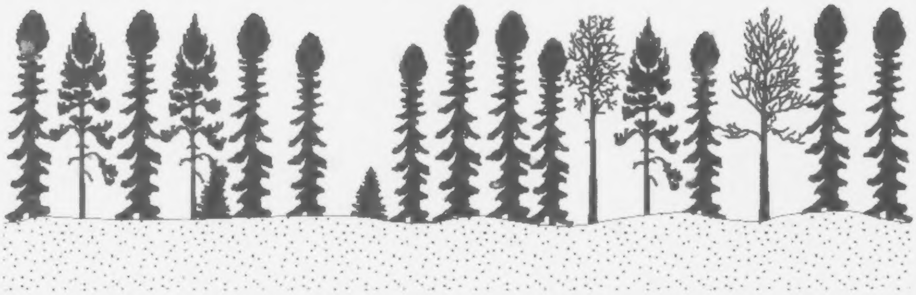
Soil Types: S14^{5}, S13^{4}, (S15, S16)^{1}.



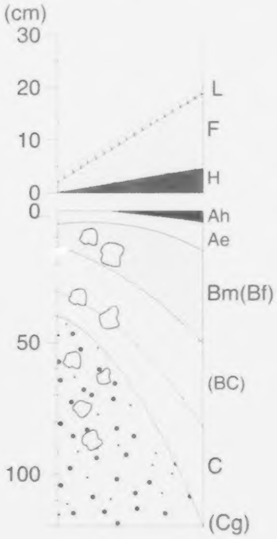
Comments: Found mainly in the Clay Belt. Free carbonates common within 100 cm of soil surface. Black spruce shrubs common in understorey.

ES 5m

Black Spruce – Medium Soil



Description: Conifer mixedwood stands dominated by black spruce, on fresh to moderately moist, medium loamy to silty soils. Shrub and herb poor with abundant feathermoss (n = 26).



Overstorey: Black spruce^{10}, Jack pine^{5}, Trembling aspen^{2}, Balsam poplar^{2}.

Shrubs: Black spruce, Balsam fir; Bunchberry, Creeping snowberry, Velvetleaf blueberry, Twinflower, Early low blueberry, Labrador-tea, Serviceberries, Bush honeysuckle, Mountain ashes.

Herbs: Wild lily-of-the-valley, Blue bead lily, Large-leaved aster, Sarsaparilla, Goldthread, Starflower.

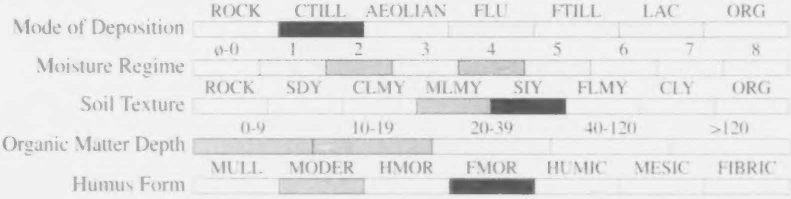
Mosses, Lichens and Liverworts: Schreber's moss, Wavy-leaved moss, Curly heron's bill moss, Plume moss, Reindeer lichen, Stair-step moss.

Vegetation Types: V20^{3}, V27^{2}, V8^{1}, V17^{1}, V19^{1}, other^{2}.

Ground Surface: Usually a continuous carpet of feathermoss with patches of conifer litter; sparse *Sphagnum*.

Landforms: Ground moraine, ablation till, end moraine and silty glaciolacustrine deposits. Moderate to many coarse fragments.

Soil Types: S9^{3}, S12^{3}, (S10, S11)^{3}, (S16, S15)^{1}.



	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG
Mode of Deposition		■					

	ø-0	1	2	3	4	5	6	7	8
Moisture Regime			▨		▨				

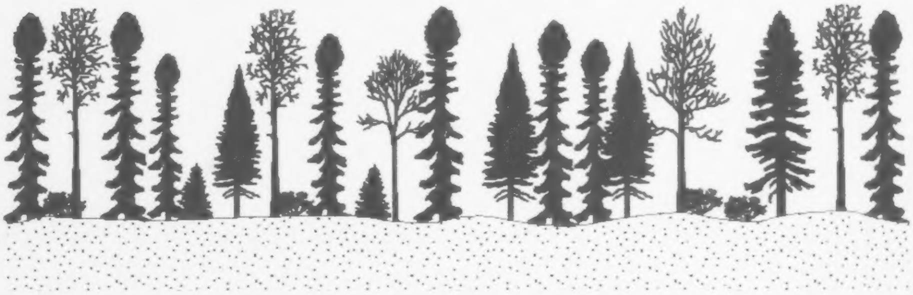
	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG
Soil Texture				▨	■			

	0-9	10-19	20-39	40-120	>120
Organic Matter Depth	▨	▨			

	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC
Humus Form		▨		■			

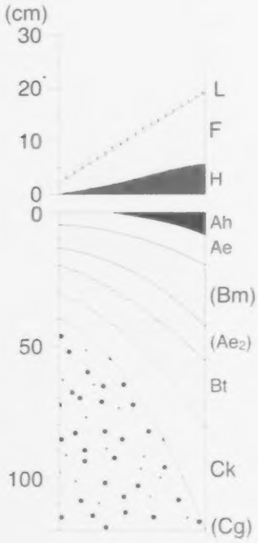
Comments: Black spruce shrubs common in understorey. Free carbonates commonly present within 100 cm of soil surface.

Black Spruce – Trembling Aspen – Fine Soil



ES 6f

Description: Mixedwood stands on fresh to moist, fine loamy to clayey soils. Medium number of shrubs, herb rich (n = 90).



Overstorey: Black spruce[8], Trembling aspen[6], Balsam fir[4], White spruce[3], Balsam poplar[2], White birch[1].

Shrubs: Balsam fir, Black spruce, Trembling aspen; Bunchberry, Dwarf raspberry, Twinflower, Bristly wild rose, Mountain ashes, Bush honeysuckle, Swamp red currant, Speckled alder, Serviceberries, Canada honeysuckle, Bristly black currant, Early low blueberry.

Herbs: Wild lily-of-the-valley, Sarsaparilla, Naked mitrewort, Violets, Fragrant bedstraw, Large-leaved aster, Blue bead lily, Sweet coltsfoot, Starflower, Wood anemone, Goldthread, Sedges, Woodland horsetail, Wild strawberry, Rose twisted-stalk, Shining clubmoss.

Mosses, Lichens and Liverworts: Schreber's moss, Plume moss, Stair-step moss, Electrified cat-tail moss, Wavy-leaved moss, Powder horn lichen, False pixie cup, Curly heron's bill moss.

Vegetation Types: V15[4], V10[1], V11[1], V12[1], V8[1], (V16, V23)[1], other[1].

Ground Surface: Varying proportions of deciduous and coniferous litter, and feathermoss.

Landforms: Glaciolacustrine or clay till plains, and undulating drumlinoid formations. Few coarse fragments.

Soil Types: S13[5], S14[4], (S15, S16)[1].

	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG
Mode of Deposition					▨	█	

	ø-0	1	2	3	4	5	6	7	8
Moisture Regime			▨	▨		▨			

	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG
Soil Texture						▨	█	

	0-9	10-19	20-39	40-120	>120
Organic Matter Depth	█	▨			

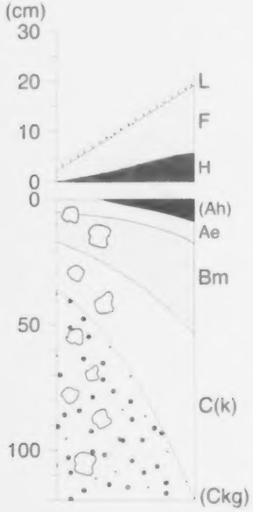
	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC
Humus Form		▨		█			

Comments: Balsam fir shrubs abundant and broad leaved shrubs common in understorey. Found mainly in the Clay Belt, with free carbonates common within 100 cm of soil surface.

ES 6m

Trembling Aspen – Black Spruce – Balsam Fir – Medium Soil

Description: Mixedwood stands on fresh to moderately moist, medium loamy to silty soils. Medium number of shrubs, herb rich (n = 24).



Overstorey: Trembling aspen^{7}, Black spruce^{6}, Balsam fir^{5}, Jack pine^{3}, White spruce^{2}, Balsam poplar^{2}, White birch^{2}.

Shrubs: Balsam fir, Trembling aspen, Bunchberry, Twinflower, Dwarf raspberry, Speckled alder, Serviceberries, Bush honeysuckle, Velvetleaf blueberry, Red raspberry, Mountain ashes, Early low blueberry, Beaked hazel, Creeping snowberry.

Herbs: Wild lily-of-the-valley, Blue bead lily, Large-leaved aster, Violets, Sarsaparilla, Wood anemone, Fragrant bedstraw, Naked mitrewort, Rose twisted-stalk, Goldthread, Sweet coltsfoot, Starflower, Sedges, Wild strawberry, Canada blue-joint.

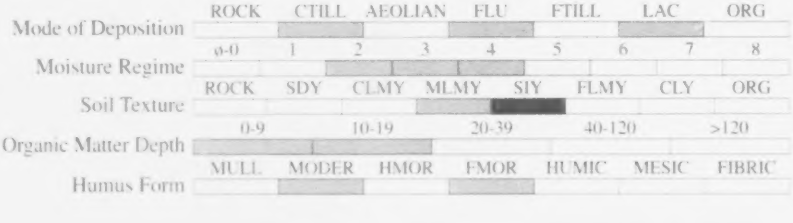
Mosses, Lichens and Liverworts: Schreber's moss, Plume moss, Stair-step moss, Wavy-leaved moss, *Brachythecium* spp., Curly heron's bill moss, Electrified cat-tail moss.

Vegetation Types: V8^{2}, V10^{2}, V15^{2}, (V11, V13, V19, V23)^{3}, other^{1}.

Ground Surface: Varying proportions of deciduous and coniferous litter, with patches of feathermoss.

Landforms: Ground moraine, ablation till, end moraine, silty glaciolacustrine or alluvial (riverine) deposits. Few coarse fragments.

Soil Types: S12^{3}, S10^{3}, S11^{1}, S16^{1}, S15^{1}, S9^{1}.



	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG
Mode of Deposition		▨		▨		▨	

	ø-0	1	2	3	4	5	6	7	8
Moisture Regime			▨	▨	▨				

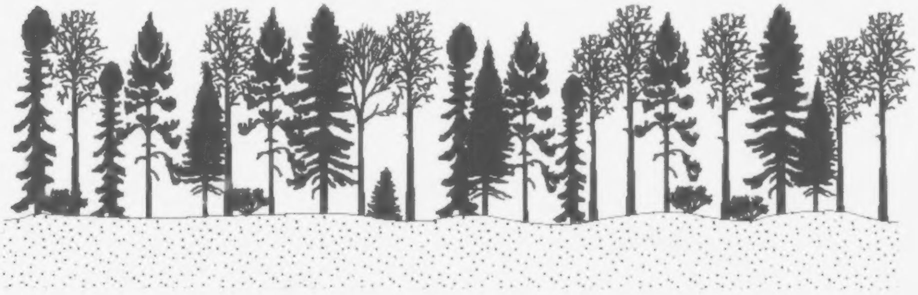
	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG
Soil Texture				▨	■			

	0-9	10-19	20-39	40-120	>120
Organic Matter Depth	▨	▨			

	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC
Humus Form		▨		▨			

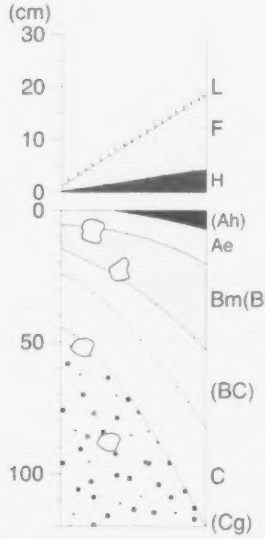
Comments: Free carbonates commonly present within 100 cm of soil surface.

Trembling Aspen – Black Spruce – Jack Pine – Coarse Soil



ES 6c

Description: Hardwood mixedwood stands on dry to moderately moist, sandy to coarse loamy soils. Medium number of shrubs and herbs (n = 49).



Overstorey: Trembling aspen[7], Black spruce[6], Jack pine[6], Balsam fir[4], White spruce[4], White birch[2].

Shrubs: Balsam fir, Black spruce, Trembling aspen, White birch, White spruce; Bunchberry, Twinflower, Bush honeysuckle, Early low blueberry, Dwarf raspberry, Serviceberries, Velvetleaf blueberry, Bristly wild rose, Beaked hazel, Mountain ashes.

Herbs: Wild lily-of-the-valley, Blue bead lily, Sarsaparilla, Starflower, Large-leaved aster, Violets, Wood anemone, Goldthread, Rose twisted-stalk, Ground pine, Running clubmoss.

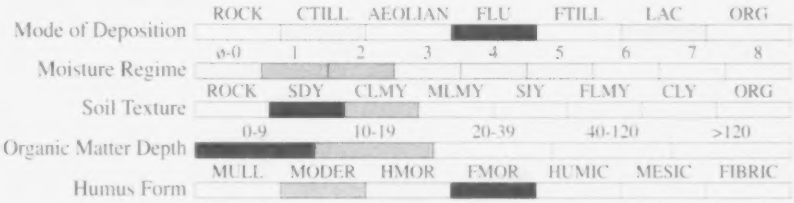
Mosses, Lichens and Liverworts: Schreber's moss, Plume moss, Wavy-leaved moss, Curly heron's bill moss, Stair-step moss, Electrified cat-tail moss.

Vegetation Types: V8[7], V4[1], V15[1], other[1].

Ground Surface: Varying proportions of deciduous and coniferous litter, with patches of feathermoss.

Landforms: Outwash plains, eskers, kames, esker/kame complexes, beaches, end moraines, ablation till, and ground moraines. Moderate to many coarse fragments.

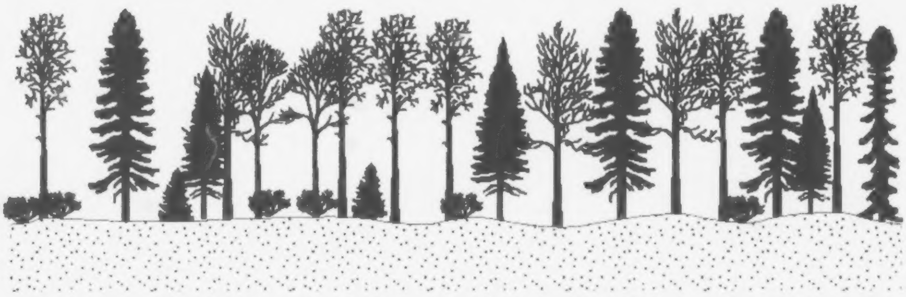
Soil Types: S2[4], S5[1], S1[1], S3[1], S6[1], S8[1], (S4, S7)[1].



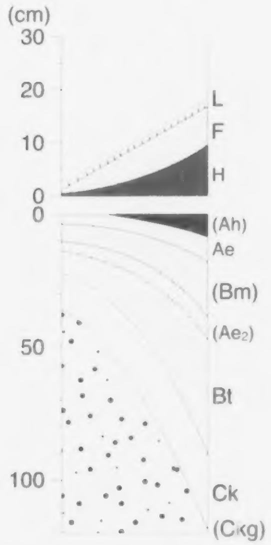
Comments: Balsam fir shrubs present in understorey of many stands. Broad leaved shrubs often found in understorey. Balsam poplar occurs less often than in ES6f and ES6m. Free carbonates common within 100 cm of soil surface.

Trembling Aspen – White Spruce – White Birch – Fine Soil

ES 7f



Description: Hardwood mixedwood stands on fresh to moist, fine loamy to clayey soils. Medium number of shrubs, herb rich with abundant tall woody shrubs (n = 69).



Overstorey: Trembling aspen^{7}, White spruce^{5}, White birch^{4}, Balsam fir^{4}, Balsam poplar^{2}, Black spruce^{1}.

Shrubs: Balsam fir, Trembling aspen, White birch; Dwarf raspberry, Mountain maple, Bunchberry, Beaked hazel, Canada honeysuckle, Mountain ashes, Bush honeysuckle, Bristly black currant, Squashberry, Bristly wild rose.

Herbs: Sarsaparilla, Blue bead lily, Large-leaved aster, Violets, Wild lily-of-the-valley, Rose twisted-stalk, Naked mitrewort, Starflower, Fragrant bedstraw, Wood anemone, Sedges, Oak fern.

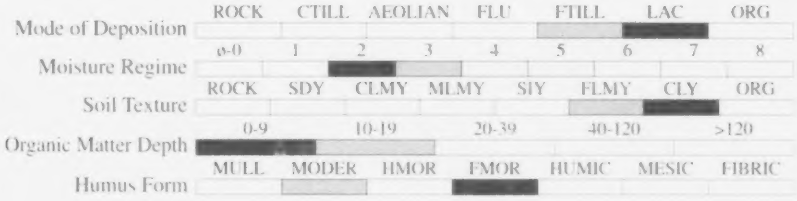
Mosses, Lichens and Liverworts: Schreber's moss, Electrified cat-tail moss.

Vegetation Types: V13^{3}, V12^{2}, V5^{2}, V4^{1}, V10^{1}, other^{1}.

Ground Surface: Abundant deciduous litter with feathermoss and conifer litter present.

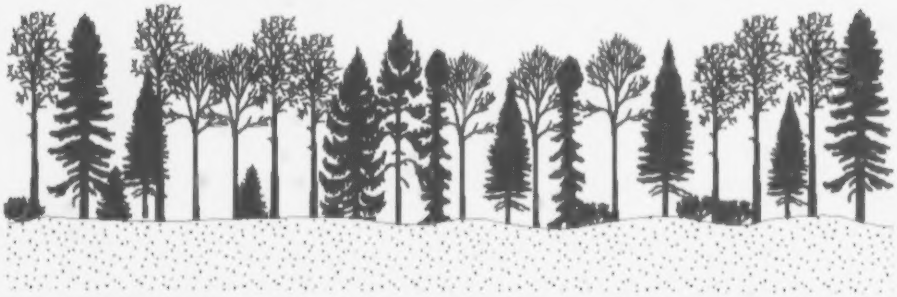
Landforms: Glaciolacustrine or clay till plains, undulating drumlinoid formations. Few coarse fragments.

Soil Types: S13^{6}, S14^{3}, (S15, S16)^{1}.



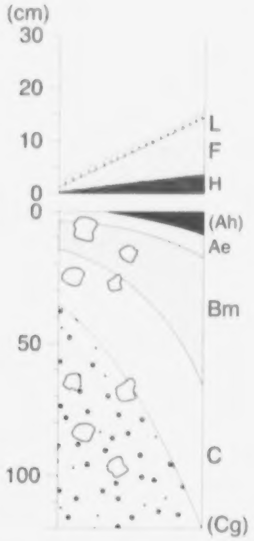
Comments: Found mainly in the Clay Belt. Free carbonates common within 100 cm of soil surface. Abundant balsam fir shrubs and tall shrubs in understorey.

Trembling Aspen – White Birch – Medium Soil



ES 7m

Description: Hardwood mixedwood stands on fresh to moist, medium loamy to silty soils. Medium number of shrubs and herbs, with abundant tall shrubs (n = 48).



Overstorey: Trembling aspen^{7}, White birch^{5}, Balsam fir^{4}, White spruce^{4}, Black spruce^{3}, Jack pine^{1}, White cedar^{1}.

Shrubs: Balsam fir, White birch, Trembling aspen, White spruce; Mountain maple, Bunchberry, Beaked hazel, Bush honeysuckle, Canada honeysuckle, Dwarf raspberry, Mountain ashes, Twinflower.

Herbs: Blue bead lily, Sarsaparilla, Wild lily-of-the-valley, Starflower, Large-leaved aster, Rose twisted-stalk, Violets, Fragrant bedstraw, Goldthread, Sedges, Spinulose shield fern, Ground pine.

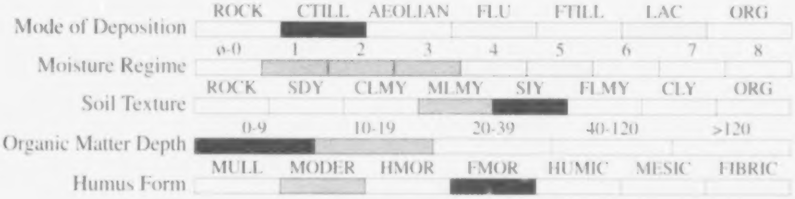
Mosses, Lichens and Liverworts: Schreber's moss, Curly heron's bill moss, *Brachythecium* spp., Plume moss, Wavy-leaved moss.

Vegetation Types: V8^{2}, V5^{2}, V4^{1}, V13^{1}, V1^{1}, V12^{1}, other^{2}.

Ground Surface: Abundant deciduous litter with feathermoss and conifer litter present.

Landforms: Ground moraine, ablation till, end moraine, silty glaciolacustrine or alluvial (riverine) deposits. Few to many coarse fragments.

Soil Types: S9^{4}, S10^{2}, S11^{2}, (S12, S15)^{2}.



	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG
Mode of Deposition		■					

	0-0	1	2	3	4	5	6	7	8
Moisture Regime		▨	▨	▨					

	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG
Soil Texture				▨	■			

	0-9	10-19	20-39	40-120	>120
Organic Matter Depth	■	▨			

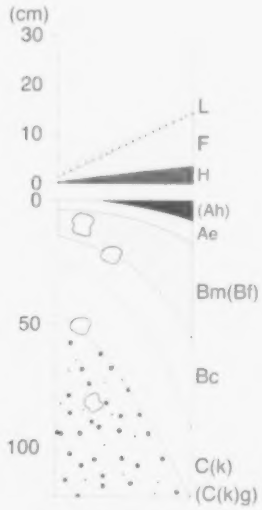
	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC
Humus Form		▨		■			

Comments: Abundant tall shrubs (especially mountain maple). Balsam fir shrubs present in understorey. Free carbonates often found within 100 cm of soil surface.

ES 7c

Trembling Aspen – White Birch – Coarse Soil

Description: Hardwood mixedwood stands on dry to moderately moist, sandy to coarse loamy soils. Medium number of shrubs and herbs with abundant tall shrubs (n = 54).



Overstorey: Trembling aspen^{8}, White birch^{5}, White spruce^{4}, Balsam fir^{4}, White cedar^{2}, Black spruce^{1}.

Shrubs: Balsam fir, White birch; Mountain maple, Bunchberry, Bush honeysuckle, Beaked hazel, Canada honeysuckle, Dwarf raspberry, Twinflower, Mountain ashes.

Herbs: Wild lily-of-the-valley, Blue bead lily, Sarsaparilla, Large-leaved aster, Starflower, Rose twisted-stalk, Violets, Ground pine, Fragrant bedstraw.

Mosses, Lichens and Liverworts: Schreber's moss, Curly heron's bill moss, *Brachythecium* spp., Sickle moss.

Vegetation Types: V4^{4}, V5^{2}, V1^{1}, V16^{1}, (V2, V12, V8)^{1}, other^{1}.

Ground Surface: Abundant deciduous litter with feathermoss and conifer litter present.

Landforms: Outwash plains, eskers, kames, esker/kame complexes, beaches, end moraine, coarse textured ablation till, or ground moraine, sandy lakebed deposits. Few to many coarse fragments.

Soil Types: S5^{3}, S7^{2}, S1^{2}, S2^{1}, (S6, S3, S4, S15, S8)^{2}.

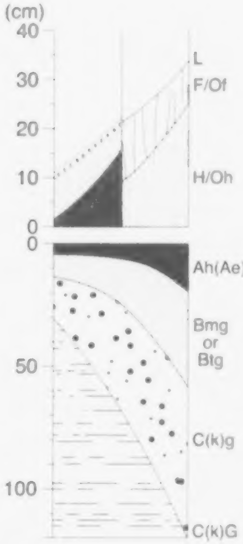
	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG		
Mode of Deposition		▨		■					
	0-0	1	2	3	4	5	6	7	8
Moisture Regime			▨	▨					
	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG	
Soil Texture		▨	■						
	0-9	10-19	20-39	40-120	>120				
Organic Matter Depth	■								
	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC		
Humus Form		▨		■					

Comments: Balsam fir shrubs and mountain maple abundant in understorey. Free carbonates often present within 100 cm of soil surface.

White Spruce – Balsam Fir – White Cedar – Moist Soil – Species Rich

ES 9r

Description: Conifer stands on moist sandy to clayey (all mineral soils). Medium number of shrubs, herb rich (n = 27).



Overstorey: White spruce[9], Balsam fir[6], White birch[5], Black spruce[3], White cedar[3].

Shrubs: Balsam fir, White birch, Black spruce, White cedar; Dwarf raspberry, Bunchberry, Mountain ashes, Mountain maple, Twinflower, Speckled alder, Swamp red currant, Canada honeysuckle, Creeping snowberry, Bristly black currant, Serviceberries, Bristly wild rose, Red osier dogwood, Red raspberry.

Herbs: Sarsaparilla, Blue bead lily, Wild lily-of-the-valley, Starflower, Goldthread, Violets, Fragrant bedstraw, Oak fern, Sedges, Naked mitrewort, Rose twisted-stalk, Spinulose shield fern, Woodland horsetail, Wood anemone, Interrupted clubmoss, Sweet coltsfoot, Northern bluebells, Large-leaved aster, Northern lady fern, Dwarf rattlesnake plantain.

Mosses, Lichens and Liverworts: Schreber's moss, Plume moss, Stair-step moss, Curly heron's bill moss, Electrified cat-tail moss, Wavy-leaved moss, Sickle moss.

Vegetation Types: V16[4], V14[1], V13[1], V15[1], V1[1], V8[1], other[1].

Ground Surface: Abundant feathermoss with very little *Sphagnum* moss; deciduous and conifer litter abundant, with few small water-filled depressions.

Landforms: Poorly drained soils, often peaty, on lower slopes on a variety of materials and landforms. Few coarse fragments.

Soil Types: S15[3], S16[2], S14[2], S11[1], (S12, S3)[1], (S7, S8)[1].

	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG
Mode of Deposition		▨		▨		▨	

	0-0	1	2	3	4	5	6	7	8
Moisture Regime							■		

	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG
Soil Texture					▨	▨		

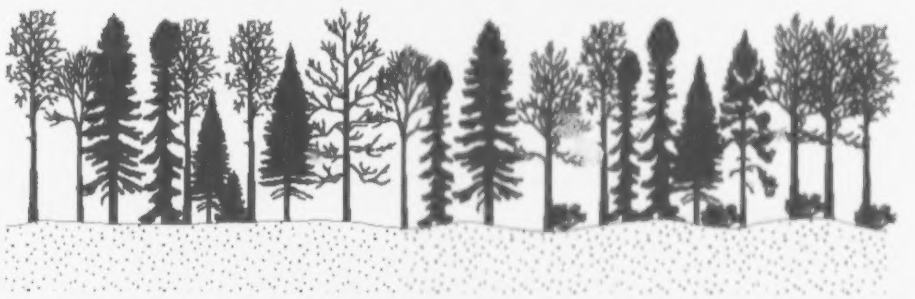
	0-9	10-19	20-39	40-120	>120
Organic Matter Depth	▨	▨	▨		

	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC
Humus Form			▨	▨			

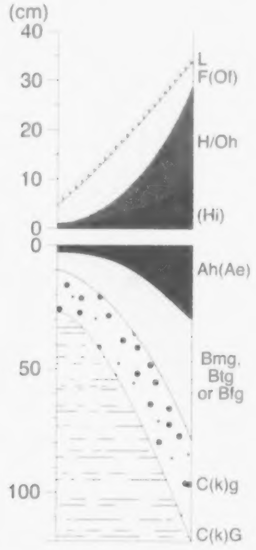
Comments: Often found on telluric lower slope positions associated with nutrient enriched seepage flow. Broad leaved shrubs common, white cedar shrubs common, balsam fir shrubs present in understorey. Free carbonates common within 100 cm of soil surface.

Trembling Aspen – Black Spruce – Balsam Poplar – Moist Soil

ES 10



Description: Hardwood mixedwood stands on moist, sandy to clayey (all mineral soil types) soils. Medium number of shrubs, herb rich, speckled alder common (n = 89).



Overstorey: Trembling aspen^{5}, Black spruce^{4}, Balsam poplar^{4}, Balsam fir^{3}, White spruce^{3}, White birch^{2}, Jack pine^{1}, Black ash^{1}.

Shrubs: Balsam fir, Black spruce, Trembling aspen; Dwarf raspberry, Bunchberry, Speckled alder, Bristly wild rose, Red raspberry, Twinflower, Bristly black currant, Serviceberries, Mountain ashes, Swamp red currant, Mountain maple, Red osier dogwood.

Herbs: Wild lily-of-the-valley, Violets, Naked mitrewort, Fragrant bedstraw, Starflower, Sarsaparilla, Blue bead lily, Large-leaved aster, Spinulose shield fern, Sweet coltsfoot, Sedges, Goldthread, Woodland horsetail, Canada blue-joint, Oak fern.

Mosses, Lichens and Liverworts: Schreber's moss, Plume moss, Curly heron's bill moss, Electrified cat-tail moss.

Vegetation Types: V10^{1}, V15^{1}, V13^{1}, V8^{1}, (V4, V11, V12, V14, V7)^{2}, other^{2}.

Ground Surface: Abundant deciduous litter with conifer litter and feathermoss present, few small water-filled depressions.

Landforms: Glaciolacustrine silts and clays or clay tills, silt pockets in morainal or glaciofluvial complexes. Few to moderate coarse fragments.

Soil Types: S14^{3}, S15^{2}, S16^{2}, S11^{1}, other^{2}.

	ROCK	CTILL	AEOLIAN	FLU	FTILL	LAC	ORG
Mode of Deposition		▨			▨	▨	

	ø-0	1	2	3	4	5	6	7	8
Moisture Regime						▨	■		

	ROCK	SDY	CLMY	MLMY	SIY	FLMY	CLY	ORG
Soil Texture							▨	

	0-9	10-19	20-39	40-120	>120
Organic Matter Depth	▨	▨	▨		

	MULL	MODER	HMOR	FMOR	HUMIC	MESIC	FIBRIC
Humus Form		▨		▨			

Comments: Often found on telluric lower slope positions associated with nutrient-enriched seepage flow. On calcareous soils with characteristic Hi/Ah humus horizons. Broad leaved shrubs common in understorey. White cedar and American elm found on one percent of this ecosite. Free carbonates commonly present within 100 cm of soil surface.

APPENDIX 5: BLANK FORMS

WORKSHEET 1

Current Forest Unit ____________________

Future Forest Unit ____________________

Broad Soil Group ____________________

Current Stand Composition Type ____________________

Future Stand Composition Type ____________________

Stand Development Stage(s) ____________________

Pre-harvest Treatments	Silvicultural Systems	Harvest Methods	Logging Methods	Regeneration Treatments	Site Preparation Treatments	Tending/Cleaning Treatments	Tending/ Intermediate Stand Treatments

WORKSHEET 2

Current Forest Unit ____________________

Future Forest Unit ____________________

Broad Soil Group ____________________

Current Stand Composition Type ____________________

Future Stand Composition Type ____________________

Stand Development Stage(s) ____________________

Pre-harvest Treatments	Silvicultural Systems	Harvest Methods	Logging Methods	Regeneration Treatments	Site Preparation Treatments	Tending/Cleaning Treatments	Tending/ Intermediate Stand Treatments

An example of a pre-harvest assessment form (adapted from OMNR 1998b).

Stand Description

Date	District	Twp/Basemap/FRI map #	SFL
Licence #	Stand #s	Licence #	Gross Area (ha)

Overstorey	(1)	(2)	(3)	(4)
Species				
Avg. DBH (cm)				
Average Ht. (m)				
Age				
Density (sph)				
Site Index				
Basal Area by Size Classes (m^2/ha)	P SS MS LS	P SS MS LS	P SS MS LS	P SS MS LS
Volume (m^3/ha)				
Product				

Site Description

Landform	Terrain	Slope Position	Slope %	Aspect	Other (rock, frost, etc.)

Forest Ecosystem Classification

Ecosite Type		
Vegetation Type		
Soil Type		
Broad Soil Group		

Soil Attributes (optional)

organic matter depth ____________

humus form ____________

depth to restrictive layer ____________

moisture regime/drainage ____________

depth to mottles/gley ____________

soil texture class ____________

Shrub Layer			Advance Regeneration			
Species	% Cover	Height (m)	Species	Height (m)	Density (sph)	Condition

Windthrow Risk	
Overstorey Composition	
Subcanopy Composition	
Stage of Stand Development	
Current Forest Condition	

An example of a pre-harvest prescription form (adapted from OMNR 1998b).

Objectives		**Silvicultural Prescription** Name of person completing the prescription ____________	Date ________
Harvesting Plan (Preferred)			
Harvest stand now? ☐ Yes ☐ No	Reasons for No	Scheduling of Partial Cuts – Selection & Shelterwood	
Start (Season/Year)	Finish (Season/Year)	Seasonal Comments (if applicable)	
Silvicultural System		Logging Method	
Constraint(s)		Volume Expected	
Cost $		Special Conditions (reserves, etc.)	
Utilized species	Leave Species		
Rationale		Access	
Renewal Plan			
Preferred		Alternative	
Site Preparation Method		Site Preparation Method	
Year/Season		Year/Season	
Microsite Objective		Microsite Objective	
Constraint(s)	Cost $	Constraint(s)	Cost $
Rationale		Rationale	
Regeneration Method	Yr/Season/Spp/Stock Type	Regeneration Method	Yr/Season/Spp/Stock Type
Target Densities	Cost $	Target Densities	Cost $
Rationale		Rationale	
Tending Method	Year/Season	Tending Method	Year/Season
Tending Objective	Cost $	Tending Objective	Cost $
Constraint(s)	Cost $	Constraint(s)	Cost $
Rationale		Rationale	
Monitoring			
Survey Schedule (Type & Year)			